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North Carolina State University at Raleigh

RECORD

THE GRADUATE SCHOOL CATALOG

1966 1968

NORTH CAROLINA STATE RECORD

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North Carolina State University at Raleigh

THE GRADUATE SCHOOL CATALOG

1966 - 1968

CONTENTS

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THE CALENDAR*

Summer Sessions, 1966

First Session

June 7	Tues.	Registration and payment of fees, 9:00 a.m. until 1:00 p.m. Late registration fee payable by all who register after 1:00 p.m.
June 8	Wed.	Classes begin.
June 13	Mon.	Last day for registration. Last day to withdraw with refund less $7 registration fee and last day to drop courses without grades.
June 14	Tues.	*Last day for filing application for admission to candidacy for students expecting to complete requirements for the master's degree in August.*
June 17	Fri.	*Deadline for submission of theses in final form to Graduate School by candidates for the master's and doctoral degrees in July. Last day for taking final oral examinations by candidates for master's degrees not requiring theses.*
June 28	Tues.	*Last day for taking qualifying examinations for students expecting to receive doctorate in January, 1967.*
July 4	Mon.	Holiday.
July 14	Thurs.	Last day of classes.
July 15	Fri.	Final examinations.

Second Session

July 19	Tues.	Registration and payment of fees, 9:00 a.m. until 12:00 noon. Late registration fee payable by all who register after 12:00 noon.
July 20	Wed.	Classes begin.
July 25	Mon.	Last day to register. Last day to withdraw with refund less $7 registration fee and last day to withdraw without grades.
July 28	Thurs.	*Deadline for submission of theses in final form to Graduate School by candidates for the master's and doctoral degrees in August. Last day for taking final oral examinations by candidates for master's degrees not requiring theses.*
August 24	Wed.	Last day of classes.
August 25	Thurs.	Final examinations.

Fall Semester, 1966

September 6	Tues.	General faculty meeting. Last day to preregister for fall courses.

* Calendar is subject to change. *Any changes will be announced in the Official Bulletin well in advance.*

September 9-11	Fri.-Sun.	Complete registration and pick up class schedules.
September 12	Mon.	First day of classes.
September 16	Fri.	Last day to add a course. *Last day for filing application for admission to candidacy for students expecting to complete requirements for the master's degree in January, 1967.*
September 23	Fri.	Last day to withdraw (or drop a course) with refund; last day to drop a course without a grade.
November 5	Sat.	Mid-term reports due. *Last day for taking qualifying examinations for students expecting to receive doctorate in May, 1967.*
November 7	Mon.	*Meeting of the Graduate Executive Council of the University of North Carolina.*
November 22	Tues.	Thanksgiving holidays begin at 10:00 p.m.
November 28	Mon.	Classes resume at 8:00 a.m.
December 16	Fri.	*Deadline for submission of theses in final form to Graduate School by candidates for the master's and doctoral degrees in January, 1967. Last day for taking final oral examinations for master's degrees not requiring theses.*
December 17	Sat.	Christmas holidays begin at 1:00 p.m.
January 3, 1967	Tues.	Classes resume at 8:00 a.m.
January 11	Wed.	Last day of classes.
January 12	Thurs.	Reading day.
January 13-20	Fri.-Fri.	Final examinations.
January 16	Mon.	*Meeting of the Graduate Executive Council of the University of North Carolina.*

Spring Semester, 1967

January 24	Tues.	Last day to preregister.
January 27-29	Fri.-Sun.	Complete registration and pick up class schedules.
January 30	Mon.	First day of classes.
February 3	Fri.	Last day to add a course. *Last day for filing application for admission to candidacy for students expecting to complete requirements for the master's degree in May and July, 1967.*
February 10	Fri.	Last day to withdraw (or drop a course) with refund; last day to drop a course without a grade.
March 18	Sat.	Mid-term reports due.
March 22	Wed.	Easter holidays begin at 10:00 p.m.
March 25	Sat.	*Last day for taking qualifying examinations for students expecting to receive doctorate in August, 1967.*
March 28	Tues.	Classes resume at 8:00 a.m.
April 3	Mon.	*Meeting of the Graduate Executive Council of the University of North Carolina.*

April 28	Fri.	*Deadline for submission of theses in final form to the Graduate School by candidates for the master's and doctoral degrees in May, 1967. Last day for taking final oral examinations by candidates for master's degrees not requiring theses.*
May 17	Wed.	Last day of classes.
May 18	Thurs.	Reading day.
May 19-26	Fri.-Fri.	Final examinations.
May 27	Sat.	Commencement.

Summer Sessions, 1967

First Session

June 6	Tues.	Registration and payment of fees; late registration fee payable by those who register after 1:00 p.m.
June 7	Wed.	First day of classes.
June 12	Mon.	Last day to register; last day to withdraw (or drop a course) with refund; last day to drop a course without a grade.
June 13	Tues.	*Last day for filing application for admission to candidacy for students expecting to complete requirements for the master's degree in August, 1967.*
June 16	Fri.	*Deadline for submission of theses in final form to Graduate School by candidates for the master's and doctoral degrees in July, 1967. Last day for taking final oral examinations by candidates for master's degrees not requiring theses.*
June 28	Wed.	*Last day for taking qualifying examinations for students expecting to receive doctorate in January, 1968*
July 13	Thurs.	Last day of classes.
July 14	Fri.	Final examinations.

Second Session

July 18	Tues.	Registration and payment of fees; late registration fee for those who register after 12:00 noon, July 18.
July 19	Wed.	First day of classes.
July 24	Mon.	Last day to register; last day to withdraw (or drop a course) with refund; last day to drop a course without a grade.
July 27	Thurs.	*Deadline for submission of theses in final form to Graduate School by candidates for the master's and doctoral degrees in August. Last day for taking final oral examinations by candidates for master's degrees not requiring theses.*
August 23	Wed.	Last day of classes.
August 24	Thurs.	Final examinations.

Fall Semester, 1967

September 5	Tues.	General faculty meeting; last day to preregister for fall courses.
September 8-10	Fri.-Sun.	Complete registration and pick up class schedules.
September 11	Mon.	First day of classes.
September 15	Fri.	Last day to add a course. *Last day for filing application for admission to candidacy for students expecting to complete requirements for the master's degree in January, 1968.*
September 22	Fri.	Last day to withdraw (or drop a course) with refund; last day to drop a course without a grade.
November 4	Sat.	Mid-term reports due. *Last day for taking qualifying examinations for students expecting to receive doctorate in May, 1968.*
November 6	Mon.	*Meeting of the Graduate Executive Council of the University of North Carolina.*
November 21	Tues.	Thanksgiving holidays begin at 10:00 p.m.
November 27	Mon.	Classes resume at 8:00 a.m.
December 15	Fri.	*Deadline for submission of theses in final form to Graduate School by candidates for the master's and doctoral degrees in January, 1968. Last day for taking final oral examinations for master's degrees not requiring theses.*
December 16	Sat.	Christmas holidays begin at 1:00 p.m.
January 2, 1968	Tues.	Classes resume at 8:00 a.m.
January 10	Wed.	Last day of classes.
January 11	Thurs.	Reading day.
January 12-19	Fri.-Fri.	Final examinations.
January 15	Tues.	*Meeting of the Graduate Executive Council of the University of North Carolina.*

Spring Semester, 1968

January 23	Tues.	Last day to preregister.
January 26-28	Fri.-Sun.	Complete registration and pick up class schedules.
January 29	Mon.	First day of classes.
February 2	Fri.	Last day to add a course. *Last day for filing application for admission to candidacy for students expecting to complete requirements for the master's degree in May and July, 1968.*
February 9	Fri.	Last day to withdraw (or drop a course) with refund; last day to drop a course without a grade.
March 16	Sat.	Mid-term reports due.
March 23	Sat.	*Last day for taking qualifying examinations for students expecting to receive doctorate in August, 1968.*

April 1	Mon.	*Meeting of the Graduate Executive Council of the University of North Carolina.*
April 10	Wed.	Easter holidays begin at 10:00 p.m.
April 17	Wed.	Classes resume at 8:00 a.m.
April 26	Fri.	*Deadline for submission of theses in final form to Graduate School by candidates for the master's and doctoral degrees in May, 1968. Last day for taking final oral examinations for master's degrees not requiring theses.*
May 15	Wed.	Last day of classes.
May 16	Thurs.	Reading day.
May 17-24	Fri.-Fri.	Final examinations.
May 25	Sat.	Commencement.

Summer Sessions, 1968

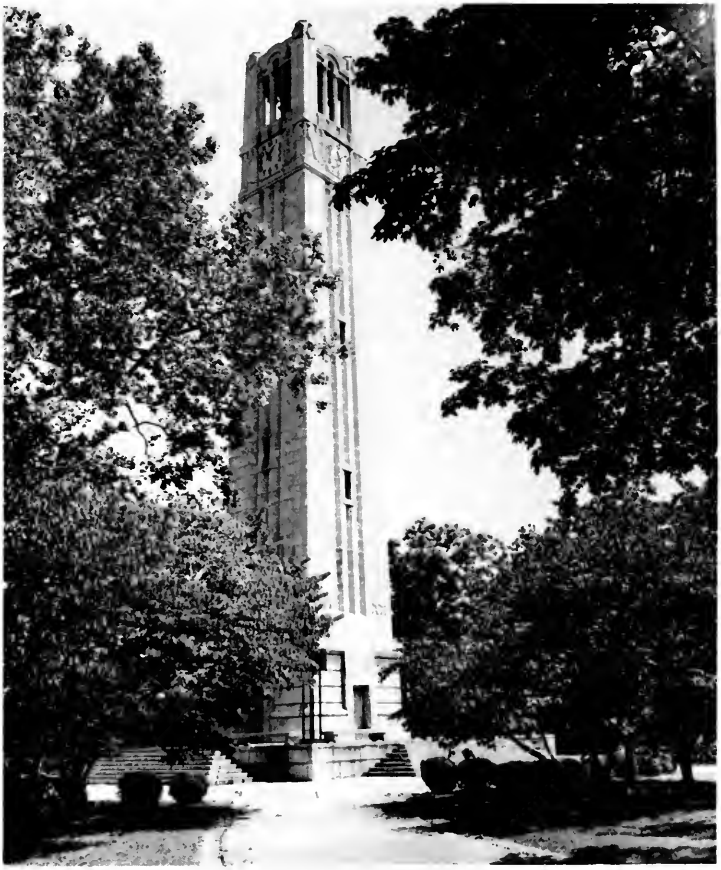
First Session

June 4	Tues.	Registration and payment of fees; late registration fee for those who register after 1:00 p.m., June 4.
June 5	Wed.	First day of classes.
June 10	Mon.	Last day to register; last day to withdraw (or drop a course) with refund; last day to drop a course without a grade.
June 11	Tues.	*Last day for filing application for admission to candidacy for students expecting to complete requirements for the master's degree in August, 1968.*
June 14	Fri.	*Deadline for submission of theses in final form to Graduate School by candidates for the master's and doctoral degrees in July, 1968. Last day for taking final oral examinations by candidates for master's degrees not requiring theses.*
June 26	Wed.	*Last day for taking qualifying examinations for students expecting to receive doctorate in January, 1969.*
July 11	Thurs.	Last day of classes.
July 12	Fri.	Final examinations.

Second Session

July 16	Tues.	Registration and payment of fees; late registration fee for those who register after 12:00 noon, July 16.
July 17	Wed.	First day of classes.
July 18	Thurs.	Last day to register; last day to withdraw (or drop a course) with refund; last day to drop a course without a grade.

July 25	Thurs.	*Deadline for submission of theses in final form to Graduate School by candidates for the master's and doctoral degrees in August, 1968. Last day for taking final oral examinations by candidates for master's degrees not requiring theses.*
August 21	Wed.	Last day of classes.
August 22	Thurs.	Final examinations.



Memorial Tower, located at the main entrance to the campus, has become the traditional symbol of North Carolina State University. Carillon bells chime hourly from the 122 foot tower, built in memory of State alumni who died in World War I.

NORTH CAROLINA STATE UNIVERSITY
at Raleigh

North Carolina State University is the center for scientific and technological education, research, and service in North Carolina. Created in 1887 by act of the North Carolina legislature as the state's land-grant institution, State was established primarily as a school of agriculture and mechanic arts. In the 77 years since its founding, however, its interests and responsibilities have been greatly broadened in response to the major scientific and technological demands of our rapidly changing world. While maintaining deep commitments to the agricultural and industrial interests of North Carolina, State has developed training and research programs of regional as well as national influence.

North Carolina State University is one of four institutions comprising the consolidated University of North Carolina. As a unit of the consolidated University, North Carolina State fulfills particular responsibilities for specialization in graduate and undergraduate training. Emphasis at State centers in the areas of agriculture, the sciences, engineering, architecture and design, forestry, and textiles.

State's organization includes eight undergraduate schools, the Graduate School, and the Division of Continuing Education. A total of 75 degrees are offered at the undergraduate level; at the graduate level there are 42 master's and 29 doctoral degree programs offered. Graduate instruction was first offered at North Carolina State in 1893. The first doctoral degree was awarded in 1926.

The eight undergraduate schools at State are the Schools of Agriculture and Life Sciences, Design, Education, Engineering, Forestry, Liberal Arts, Physical Sciences and Applied Mathematics, and Textiles. The research, extension, and instructional programs of these schools are supported and strengthened by several specialized divisions and offices including the Institutes of Statistics, Water Resources, Agricultural Policy, and Biological Sciences; the Computing Center; the Agricultural and Industrial Extension Services; and the Agricultural Experiment Station with its 17 branch stations. State's facilities also include a minerals laboratory and a fisheries research station.

The North Carolina State campus, with adjoining research farms, covers 3,000 acres and is valued at more than $70 million. There are 80 major University buildings, including classroom, laboratory, and auxiliary facilities buildings. In addition to the Raleigh campus, State operates a number of agricultural research farms and extensive experimental forests.

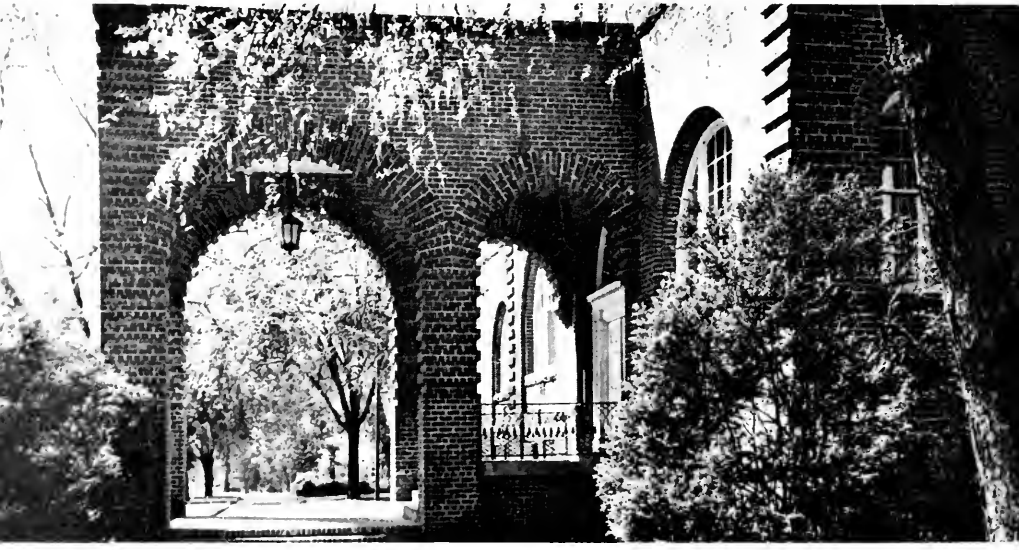
Undergraduate enrollment at State is currently about 9,800; in the fall semester of 1965 the Graduate School had enrolled 1,601 students. A large international student group representing 60 countries is presently studying at State.

The University faculty and staff numbers more than 1,500 members, including a graduate faculty of 473.

For 1965-66, State's budget will exceed $36 million. In order to accommodate the growing enrollment and the increasing research requirements, North Carolina State University is pursuing a continuing program of building and acquiring new faculty and research staff. The present research expenditure is about $12 million annually. Current research appropriations, contracts and grants total more than $17 million.

State is contributing to international development through an agricultural mission to Peru, special soils studies programs for Latin America, and a cooperative project with the University of Kabul, Afghanistan. Scores of international visitors, individual faculty work with universities in other countries, and the large international student enrollment at State indicate the extent of the University's international involvement.

North Carolina State is accredited by the Southern Association of Colleges and Schools and the North Carolina College Conference. In addition, individual schools and departments are accredited by various associations in their respective fields. State holds memberships in the Association of State Universities and Land-Grant Colleges, the American Council of Education, the College Entrance Examination Board, the Council of Graduate Schools in the United States, the National Commission on Accrediting, the Oak Ridge Institute of Nuclear Studies, and the Southern Association of Colleges and Schools.



Holladay Hall houses many of State's administrative offices. The building, oldest on campus, was erected in 1889 and is named in honor of Alexander Q. Holladay, first president of the college.

THE GRADUATE SCHOOL
of the University of North Carolina

NORTH CAROLINA STATE UNIVERSITY DIVISION

DONALD BENTON ANDERSON, *Vice President for Academic Affairs, Chapel Hill*
WALTER JOHN PETERSON, *Dean, Raleigh*

The Graduate School of the University of North Carolina is composed of three divisions, one at the University of North Carolina at Chapel Hill, one at the University of North Carolina at Greensboro, and one at North Carolina State University at Raleigh. Each branch of the consolidated Graduate School is administered by a graduate dean who works in close association with the Vice President in Charge of Academic Affairs. The Graduate Council is composed of representatives of the Administrative Boards of each of the three units of the consolidated University having a division of the Graduate School. At North Carolina State University the graduate dean is assisted in all matters of policy by an Administrative Board of ten members. Seven are elected by the faculties of the degree-granting schools and three are appointed by the Chancellor after consultation with the Dean.

Graduate instruction at North Carolina State University is organized to provide opportunity and facilities for advanced study and research in the fields of agriculture and life sciences, engineering, forestry, physical sciences and applied mathematics, technological education, and textiles. The purpose of these graduate programs is to develop in advanced students a more adequate comprehension of the requirements and responsibilities essential for independent research investigation. In all the graduate programs emphasis is placed upon a high level of scholarship rather than upon the satisfaction of specific course or credit requirements.

The full resources of the consolidated University of North Carolina are available to all graduate students enrolled at any of the three divisions of the Graduate School. Exceptional facilities for graduate study are provided at North Carolina State University. New buildings furnish modern well equipped laboratories for graduate study in specialized areas of agriculture and life sciences, engineering, forestry, physical sciences and applied mathematics, and textiles.

The North Carolina Agricultural Experiment Station and the Department of Engineering Research are integral parts of the University at Raleigh. The staff, research facilities, equipment, and field studies of these organizations contribute in a very important way to the graduate programs. The Institute of Statistics at North Carolina State makes available to graduate students unusual opportunities in this important phase of research study.

The state of North Carolina, extending from the Atlantic Ocean westward about 500 miles to the Appalachian Mountains, possesses an exceptional range of climatic and topographic environments. The coastal plain, the Piedmont, and the mountains provide a rich pattern of agricultural and industrial activity which offer unusual opportunities for research and employment.

North Carolina State University is located in Raleigh, situated on the boundary separating the broad coastal plains on the east from the rolling terrain of the Piedmont on the west, about midway between the northern and southern boundaries of the state. Raleigh is 29 miles from the University of North Carolina at Chapel Hill and 26 miles from Durham, the home of Duke University. The libraries and other facilities of the three institutions make this area one of the important centers of research opportunity in the South.

The D. H. Hill Library

The D. H. Hill Library of North Carolina State University has excellent holdings in materials essential for research study in the graduate curricula offered by the University.

As of July 1, 1965, the library held about 332,000 volumes of books and bound journals, including more than 14,000 bound volumes of documents. The books and journals reflect strongly the scientific and technological interests of the University, and the documents represent a most important increment of the whole collection. They include publications of the federal government, all publications of the various Agricultural Experiment Stations, most of the publications of the Engineering Experiment and Engineering Research Stations, and publications of the various research stations all over the world. The library receives over 4,700 current periodicals.

The D. H. Hill Library holdings and other library holdings within a 30 mile radius of North Carolina State constitute the greatest concentration of library resources south of Washington, D. C. These include the D. H. Hill Library, the Chemstrand Research Center Library, the Duke University Library, and the Louis Round Wilson Library at the University of North Carolina at Chapel Hill.

An inter-library delivery service exchanges volumes among the three university libraries three days a week. These three libraries have a total of more than 3,000,000 volumes. This loan service serves faculty and graduate students on the three campuses. Identification certificates enabling participation in the reciprocal arrangement may be secured at the D. H. Hill Library.

A list of scientific periodicals which includes holdings of Duke University and the units of the consolidated University is available to faculty members and research scientists in the area and to other libraries throughout the nation.

The North Carolina State University library is a depository for all unclassified publications of the federal government that are

available for distribution. These include publications of the United States Department of Agriculture, Geological Survey, National Bureau of Standards, Department of Interior and others. Since the library was designated as a depository in 1923, its document holdings in the University's special interest fields are almost 100 percent complete.

The library is a depository for the publications of the Carnegie Institution of Washington and has excellent files of these valuable monographs.

Also, the library is a depository for all unclassified and declassified publications of the Atomic Energy Commission.

Publications of many foreign countries—especially publications dealing with the agricultural sciences and with engineering—are received on exchange by the library.

In July, 1960, the library became a depository for the publications of the Food and Agriculture Administration of the United Nations.

The library, in July, 1959, acquired the Tippmann Collection of Entomology, the outstanding private collection of Dr. Friedrich F. Tippmann of Vienna. The collection contains 6,200 books and bound research journals in the field of entomology, many of them rare and unobtainable.

A recent donation of $5,000 from the Alumni Association was used to purchase two outstanding sets of the rare 20-volume "Edizone Nazionale" of the works of Galileo and an almost complete file of the important German botanical periodical, "Bibliotheca Botanica," covering the years 1889 to 1960.

Funds from the estate of the late Chancellor J. W. Harrelson have been allocated to purchase rare volumes in mathematics and history of science and important files of research journals.

The research holdings of the library are particularly strong in the fields of entomology, nuclear energy, genetics, aeronautics and space technology, engineering and physics, and include files of the major journals in these fields. A large and useful collection of books in the humanities and the social sciences is available for the use of undergraduate students.

The library's photocopy service is of great importance to faculty and graduate students in that it provides facilities for copying materials not permitted to leave the library.

The Textiles Library, an on-campus branch of the main library, contains outstanding holdings in textiles and textile chemistry. It is regarded as one of the best textiles libraries in the country. The School of Design Library has a very fine collection of books, journals and slides in the fields of architecture, landscape architecture and product design.

Institute of Statistics

The Institute of Statistics is composed of two sections, one at Raleigh and the other at Chapel Hill. At North Carolina State, the

Institute provides statistical consulting services to all branches of the institution, sponsors research in statistical theory and methodology, and coordinates the teaching of statistics at the undergraduate and graduate levels. The actual instructional and other academic functions are performed by the Department of Experimental Statistics, which forms a part of the Institute.

The purpose of the Institute is to provide extra depth and strength in the development and use of modern statistical procedures throughout the University. This involves cooperative efforts with many schools, departments, and agencies. The establishment of a nationally recognized program in quantitative genetics and recent developments in the field of biomathematics illustrate the coordinating role the Institute plays in the quantitative sciences.

In addition to these local activities, the Institute maintains close and continuing contact with statistics scholars, research programs, and graduate instruction programs throughout the world. It has helped develop an international abstracting journal for statistical articles. The Institute is the point of contact for grants and contracts in statistics. It has been active in organizing and maintaining a strong Southern Regional Cooperative Graduate Summer Session in statistics. Approximately 15 graduate assistantships in statistics are made available annually through the efforts of the Institute. All of these contributions have added substantially to the vigor of the entire graduate program of North Carolina State University.

Computing Facilities

Beginning in August 1966, there will be a rather complete changeover of the equipment in the Computing Center, and of the computing organization in the Research Triangle area. Duke University, the University of North Carolina at Chapel Hill, and North Carolina State University have joined together to form the Triangle Universities Computation Center. This Center, with a large computer (IBM Systems 360, Model 75), will be located in the Research Triangle Park. Each campus computing center will be equipped with a high-speed remote unit (IBM Systems 360, Model 30), with additional medium and low-speed remote console units in convenient locations on the campus.

The above configuration replaces an IBM 1410 tape system and three IBM 1620's on the North Carolina State University campus. Part of the need for expansion resulted from the heavy graduate student training and research requirements. It is visualized that the new facilities will provide adequate computing power and time for the expanding graduate training and research program. Programming courses of both the regular credit type, as well as short courses, are offered by the Departments of Mathematics and Experimental Statistics and by the Computing Center.

Research Program at the Oak Ridge Associated Universities

North Carolina State is one of the sponsoring institutions of the Oak Ridge Associated Universities at Oak Ridge, Tennessee. Through this cooperative association, North Carolina State's graduate research program has at its disposal the facilities and research staff at Oak Ridge National Laboratory. Extensive research programs are under way there on physical and biological effects of radiation, radioisotope utilization, and many other areas of nuclear science and engineering. When master's and doctoral candidates have completed their resident work, it may be possible, by special arrangement, for them to do their thesis research at Oak Ridge. In addition, it is possible for the staff members of this University to go to Oak Ridge for advanced study in their particular fields.

Institute of Biological Sciences

The Institute of Biological Sciences is an organization within the School of Agriculture and Life Sciences of the Departments of Botany, Entomology, Genetics, Microbiology, Plant Pathology, Zoology and faculties of Biochemistry and Physiology. Its function is to encourage and promote research and teaching in basic biology and to coordinate inter-departmental activities. Program-type grants are administered by the Institute and enable grant support to be provided to discipline and subject matter areas involving faculties in several departments.

Facility planning, development and support for biological sciences is an important function of the Institute. Also, summer institutes are administered in the Institute of Biological Sciences. These have included the National Science Foundation-sponsored Summer Institutes in Genetics and Pesticide Toxicology for College Teachers, Biology for High School Teachers, and Biology, Chemistry, and Mathematics for High School Students. Academic Year Institutes in Biology for High School Teachers have also been sponsored.

The Biological Sciences Undergraduate Curriculum and the Undergraduate Research Participation for Biological Sciences are cooperative programs administered in the Institute. These programs have had an outstanding record in the percentage of individuals going into graduate study following their participation in these programs.

This organization provides a mechanism for strengthening research and instruction in existing graduate programs, and for developing new inter-disciplinary areas. Inter-departmental cooperative graduate programs have become increasingly important within the basic biological sciences and among the biological, physical, and engineering sciences. The Institute plays an important role in encouraging the full utilization of the faculties and facilities for graduate research and instruction.

Graduate Institute of Extension Education

The Graduate Institute of Extension Education provides an inter-disciplinary program by drawing together basic concepts from the behavioral sciences and education relevant to adult and extension education. The Institute is available on campus to serve instructional needs as well as the need for basic and applied research in the field.

The Institute is administered by a five-man board of directors including the Dean of the Graduate School; Deans of the Schools of Agriculture and Life Sciences, Education, and Liberal Arts at North Carolina State; and the Dean of the School of Home Economics at the University of North Carolina at Greensboro. Supplementing the efforts of the board of directors is an advisory committee representing the eight departments involved in this inter-disciplinary instructional and research program.

The Graduate School offices are located in Peele Hall, which also houses many of the offices for the Division of Student Affairs.

GENERAL INFORMATION

TUITION AND FEES

Tuition rates for students enrolled in the Graduate School at North Carolina State are as follows:

North Carolina Resident—$9 per semester hour of enrollment up to and including nine semester hours. For ten semester hours or more, $87.50 for the semester.
Non-Resident—$32 per semester hour for each semester hour of enrollment up to and including nine semester hours. For ten semester hours or more, $300 for the semester.

Incidental fees and charges are levied for purposes and services available to all graduate students whether or not the student takes advantage of them.

The full amount of incidental fees and charges will be collected, notwithstanding the number of semester hours of credit for which the student may enroll.

For the academic year 1966-67, fees are as follows:

First semester	$89.50
Second semester	$88.50

In cases of occasional or part-time graduate students not in residence, application for cancellation of non-academic fees may be made if it is clear that the student could not use the services covered. Application forms are available in the Graduate School and the Office of Business Affairs.

Full-time faculty of instructor rank and above and other full-time employees of the University who hold membership in the Teachers' and State Employees' Retirement System may register for credit or audit one course in each semester or summer term with free tuition privileges. Free tuition privileges apply only during the period of one's normal employment and do not include such other charges as registration, laboratory or other appropriate fees. Each applicant for free tuition privileges must complete and submit through regular administrative channels a form provided by the University. A maximum of 8 semester hours may be taken during the academic year.

Faculty members on less than full-time appointments will be permitted to take more than one course per semester upon the recommendation of their dean and the approval of both the Dean of the Graduate School and the Dean of the Faculty. In these cases tuition and fees will be the same as those for part-time graduate students computed at residence rates.

Maximum permissible course loads for graduate students holding part-time appointments are as follows: Three-quarters time, six hours; half-time, nine hours; quarter-time, twelve hours.

Students wishing to visit classes without participation in class discussions, quizzes, or examinations must register for this privilege as auditors. *Visiting classes without registration is not permitted.* Graduate students may register for one course as an audit in any semester without charge when the audit is certified by the Dean of the Graduate School as a part of course work for which tuition charges are made (this does not apply in the summer sessions).

Audits in subjects in which the student has had no previous experience will be evaluated at full credit value in determining course loads. Audits taken as repetition of work previously accomplished are considered at one-half their credit value in calculating course loads. With the single exception of foreign language audits, all audit registrations must fall within the maximum permissible course loads. Audits are not permitted students registering for thesis preparation. While audit registrations are evaluated for purposes of determining permissive course loads in terms of the above regulations of the Graduate School, the Office of Business Affairs considers all audits, excepting the one permitted free of charge, in terms of full credit value in calculating the tuition for graduate students.

All graduate students holding appointments of ⅓ service obligation or more and receiving a regular monthly salary check are charged the resident or "in-state" rate of tuition.

Graduate students who have completed all course work, research and residence requirements and who are in residence for the purpose of writing a thesis or dissertation may register for "thesis preparation." The tuition charge for this registration is $15. Students registering for thesis preparation will pay, in addition, fees of $89.50 in the fall semester and $88.50 in the spring semester. When not in residence these charges will be $15 plus $7 registration fee, or $22.

Graduate students not in residence who have completed all requirements for the degree sought, including the thesis and final examination, will be required to register for "degree only" in the semester in which the degree is awarded. The charge for this registration is $10.

A diploma fee of $12 is charged all students receiving a master's degree and a fee of $17 is charged all students who receive a doctorate. A fee of $21 is charged all doctoral candidates for microfilming their dissertations.

Anyone who feels a mistake has been made in his bill may discuss the matter with the Office of Business Affairs. Any further appeals should be made to the Committee on Refund of Fees. Forms for this appeal may be obtained from the Office of Business Affairs.

All tuition charges and fees are subject to change without notice.

Fees for Summer School

Registration Fee	$23.50
Tuition (In-State Students per credit hour)	$ 7.50

Tuition (Out-of-State Students per credit hour) $18.50
Audits (per credit hour) ..... $ 7.50

Residence Status

In order to draw a clear line between in-state and out-of-state students, the Administration has ruled that all students whose parents have not been domiciled in North Carolina for more than six months immediately preceding the day of their first enrollment in the institution shall be termed out-of-state students, with the following exceptions:

(1) Students twenty-one years of age at the time of their first matriculation who have resided in North Carolina for more than one year preceding the day of their first enrollment;
(2) Children of regular employees of the federal government stationed in the state of North Carolina; and
(3) Children of regular employees of the federal government who are employed outside of the state, but who through law are permitted to retain their North Carolina citizenship.

Students cannot claim a change in their resident status after matriculating. Students furnishing incomplete or incorrect information in order to obtain the special state-resident status shall be liable for dishonorable dismissal.

FELLOWSHIPS AND GRADUATE ASSISTANTSHIPS

Fellowships

Graduate fellowships and traineeships provide funds to graduate students to assist in the support of their programs of advanced study. Holders of fellowships have no service obligation to the University and may devote full time to their graduate programs.

Some of the agencies sponsoring fellowships at North Carolina State University are the Aluminum Company of America, the Atomic Energy Commission, Chemstrand, Douglas Aircraft Company, Dow Chemical Company, DuPont Company, E. Sigurd Johnson, Eastman Kodak Company, Ford Foundation, General Electric, General Food Corporation, Honor Society of Phi Kappa Phi, Kellogg, National Aeronautics and Space Administration, National Institutes of Health, National Lumber Manufacturing Association, National Science Foundation, North Carolina Grange (E. G. Moss Fellowship), North Carolina Textile Foundation, Officer of Education (Department of Health, Education and Welfare), R. J. Reynolds Tobacco Company, Research Corporation, Rockefeller Foundation, Scholler Foundation, and Shell Oil Company.

Information relative to stipends, areas of research study supported by specific fellowships, and application forms may be obtained from the Graduate School or from the heads of the appropriate departments.

Assistantships

Graduate assistantships are granted to selected students who normally devote half-time to service duties for the University. Teaching assistantships carry stipends ranging from $2,700 to $3,600 for the academic year and permit the holder to enroll for sixty percent of a full course load. The stipends for research assistantships range from $2,700 to $3,600 for a calendar year appointment.

The University offers 625 assistantships requiring a service obligation in either teaching or research. Some of these are supported by funds granted by the following agencies: the Air Force Cambridge Research Laboratories, Air Force Office of Scientific Research, the American Museum of Natural History, American Potash Institute, Army Missile Command, Army Research Office (Durham), the Atomic Energy Commission, Best Foods, Campbell Soup Company, the Chilean Nitrate Education Bureau, Inc., Gerber Products Company, Hercules Powder Company, Department of Labor, the Lilliston Implement Company, the Lilly Company, National Aeronautics and Space Administration, National Cotton Council, National Institutes of Health, National Science Foundation, Naval Applied Science Laboratory, North Carolina Agricultural Foundation, North Carolina Dairy Foundation, North Carolina Milk Commission, North Carolina Motor Carriers Association, the Office of Naval Research, Pacific Coast Borax Company, Peanut Growers Association, the Petroleum Research Fund of the American Chemical Society, Pulp and Paper Foundation, Inc., R. J. Reynolds Tobacco Company, the Ralston-Purina Company, the Solvay Process Division of the Allied Chemical Company, the Tennessee Corporation, U. S. Department of the Interior, and the Weyerhaeuser Foundation.

RESIDENCE FACILITIES

Dormitory facilities are provided on the campus for unmarried graduate students. The rental fee for double rooms in the men's residence halls is $133 per semester.

A limited number of University apartments are available for married graduate students in McKimmon Village. Rent per month, not including utilities, is as follows: efficiency, $45; one bedroom, $59.50; two bedroom, $71.

ADMISSIONS

Graduate School admission may be to full graduate standing, provisional or unclassified status. Applications for admission to the Graduate School must be accompanied by official transcripts from all colleges previously attended.

Full Graduate Standing—For admission in this category a student must have a bachelor's degree from a recognized college or university regarded as standard by a regional or general accrediting agency, and must have at least a B grade average in his undergraduate major.

Provisional admission may be granted to applicants who lack undergraduate work considered essential for graduate study in the major field. Course work, without graduate credit, will be required to make up such deficiencies before admission to full graduate status can be granted.

Graduates from non-accredited institutions may be granted *provisional admission* when their academic records warrant this status. Additional course work will be required of such students when deficiencies in their previous training are apparent.

Graduates from accredited institutions whose scholastic records are below the standards for admission to full graduate standing may be admitted provisionally when unavoidable extenuating circumstances affected their undergraduate averages or when progressive improvement in their undergraduate programs warrant provisional admission. All such students are required to take the Graduate Record Examination and to submit scores to the Graduate School office in support of their application. The National Teacher Examination may be substituted for the Graduate Record Examination if recommended by the department head. Information as to the dates on which the Graduate Record and the National Teacher Examinations are given may be obtained at the Graduate School office.

Graduate students admitted to provisional status may attain full graduate standing when the deficiencies responsible for their provisional status are corrected. They also must have maintained a satisfactory academic record in all course work taken as part of their graduate program. Change from provisional to full graduate standing is effected only on written recommendation from the department in which the student is seeking his degree.

Unclassified graduate students are not candidates for graduate degrees. They may take courses for graduate credit but may not apply more than ten credits earned while in the unclassified status to any program leading to an advanced degree at this institution. Unclassified graduate students are expected to meet the same admissions requirements that apply to graduate students in full standing.

Applications for admission to the Graduate School should be on

file in the Graduate School office at least thirty days in advance of the registration date for the term in which the student wishes to enroll in the Graduate School.

Public school personnel (primary teachers, secondary teachers, or administrators) registering at North Carolina State for the first time who are interested primarily in "Certification Credit" may enroll as graduate students for a maximum of six semester hours without forwarding official transcripts of previous work to the Graduate Office. If, however, application is not made through normal channels for graduate credit in the session in which the course or courses are taken, the student will not be permitted to apply the credit toward an advanced degree at North Carolina State, or elsewhere.

In all cases where the teacher's interest is primarily in approval for certification credit, the School of Education will be responsible for assessing the adequacy of the teacher's qualifications for enrollment in the University in the particular course or courses. The School of Education will also be responsible for advising all such students early in each school session that if they wish their credits to be applied in due course to a higher degree at North Carolina State, or elsewhere, normal admission procedures will be required.

All teachers who have previously attended North Carolina State University and earned six semester hours of credit and wish to enroll for additional courses for graduate credit will be required to make application for admission to the Graduate School in the usual manner, if they have not already done so.

In all cases a "B" level of academic performance or better is required.

Graduate-Special—This classification is used primarily for students enrolling in special institutes such as the summer institutes regularly held for college teachers, high school teachers, and graduate students, or special graduate training programs for separate groups such as our summer offerings for extension staff.

The following rules apply to students registered as Graduate-Special:

1. All must have at least a baccalaureate degree from an accredited institution of higher learning.
2. Official transcripts need not be submitted to the Graduate Office for enrollment in this classification but the appropriate institute or program director must file with the graduate dean well in advance the nature of the program, the criteria and methods used in selection of the students, and assurances that the students have adequate preparation for the course contemplated.
3. Placement in this classification carries with it no implication that students will be admitted to the Graduate School in any of the other classifications.
4. Graduate credit will be allowed not to exceed six hours of

course work at the 500 or 600 level if performance is at a "B" level or better.

5. If the student is in due course admitted to the Graduate School, graduate credit obtained under this classification may apply to an advanced degree, if in the judgment of the Advisory Committee the course(s) are germane to the particular program of work.
6. Students who have received as much as six hours of graduate credit under this classification must make application for admission to the Graduate School before permission will be granted to enroll for additional graduate work.

Registration

The Office of Registration must have written authorization from the Dean of the Graduate School before any graduate student will be given a permit to register. This authorization will be sent to the Office of Registration by the graduate dean at the time the student is notified of his acceptance.

Registration for Courses in Other Branches of the University

Graduate students working toward an advanced degree at North Carolina State University may find it desirable to enroll for certain courses in one of the other branches of the University. The following principles and procedures apply in such cases:

1. A graduate student shall be considered to remain in the Graduate School of the branch of the University to which he is admitted for a specific degree program, to be under the control of his department, to be advised by his department, and to be enrolled by that Graduate School for any graduate work which he may take for credit in his own branch or any other branch of the University.
2. A graduate student at one branch of the University who is taking work at some other branch of the University for credit toward his degree at the University branch to which he has been admitted shall be enrolled for all courses, including those at the other branch of the University, in his home Graduate School. This Graduate School shall consider courses taken at the other branch of the University as a part of the student's normal load and shall use such enrollment in computing the total billing which the home University will make to the student.
3. A student at one branch of the University who is by this method enrolled in one or more graduate courses at some other branch of the University will be admitted to these courses, provided space exists in these classes, by the Graduate School of the other branch upon normal notification by the Graduate School of the student's branch that the student has been

properly enrolled for these courses and has the approval of the home branch for this program of study.

4. During the summer sessions approval of the courses to be taken shall be asked, but the billing procedures shall be those regularly used for visiting students.
5. No student enrolled as a regular graduate student in any branch of the University shall be admitted to courses at another branch of the University without the presentation by the student of written permission from the Graduate School of the branch to which the student was originally admitted.

Physical Examinations

All regularly enrolled graduate students must take a physical examination preferably given by the family physician and the results recorded on forms provided by the University. When this is not done the examination may be given by the North Carolina State physician during registration for a fee of $10.

Course Load

A full-time graduate load is considered to be nine to fifteen credits per semester. This course load restriction is made so that graduate students may have time for reading and contemplation well beyond the limits set for satisfactory undergraduate work. In exceptional cases one or two additional credit hours may be added to the roster if necessary in order to get prerequisite work not taught in subsequent terms, provided the corresponding adjustment in course load is made in the other terms. Rosters with additional credit hours beyond fifteen should be accompanied by a special note from the head of the major department indicating the reasons for the additional work.

Full-time faculty of instructor rank and above and other full-time employees of the University who hold membership in the Teachers' and State Employees' Retirement System may register for credit or audit one course in each semester or summer term with free tuition privileges. Free tuition privileges apply only during the period of one's normal employment and do not include such other charges as registration, laboratory or other appropriate fees. Each applicant for free tuition privileges must complete and submit through regular administrative channels a form provided by the University.

Employees having academic rank higher than that of instructor may register for graduate work for credit to be transferred to other institutions. They may not undertake programs for graduate degrees at the consolidated University of North Carolina.

Graduate assistants on half-time appointments are permitted a maximum course load of nine credits per semester unless corresponding adjustments are made in their service obligations during

the same semester. If the appointment is for the academic year of nine months, half-time assistants are restricted to a maximum of eighteen credit hours of work during the nine months of their appointment. Half-time graduate assistants whose appointments are for twelve months may not exceed a total of twenty-four credits during the twelve month period of their appointment. Three-quarter time graduate assistants whose appointments are for twelve months may register for a total of sixteen credits during the calendar year. A total of six credits is the maximum load in a regular semester.

A member of the North Carolina State senior class may, upon approval of the Dean of the Graduate School, register for courses in the 500 group for graduate credit to fill a roster of studies not to exceed fifteen credits in any semester. Not more than six hours of graduate credit may be acquired by an undergraduate student. Courses listed with numbers in the 600 series are not ordinarily open to undergraduates. Occasional exceptions may be made for "honor" students.

The largest classroom facility on campus, Harrelson Hall's unusual architecture makes it a campus landmark as well as a most functional classroom building.

GRADUATE DEGREES

Admission to the Graduate School does not constitute admission to candidacy for a graduate degree. Application for admission to candidacy for graduate degrees must be submitted to the Administrative Board of the Graduate School. Applications of students preparing for the master's degree may not be filed before the satisfactory completion of one full semester of graduate study and must be presented before the end of the first week of the last semester in residence. Approval of the application will be determined by the quality of the scholastic record and on the certification by the major department that the student is qualified to continue advanced work. Admission to candidacy for the doctorate is granted upon satisfactory completion of the qualifying or preliminary examinations.

The Graduate School at North Carolina State University offers work leading to the Master of Science degree and the Professional Master's degree in certain specialized fields in the Schools of Agriculture and Life Sciences, Education, Engineering, Forestry, Physical Sciences and Applied Mathematics, and Textiles; and the Doctor of Philosophy degree in certain fields of agriculture and life sciences, engineering, forestry, and physical sciences and applied mathematics.

A graduate student is expected to familiarize himself with the requirements for the degree for which he is a candidate and is held responsible for the fulfillment of these requirements. This applies to the last dates on which theses may be accepted, the dates for examinations, the proper form of theses, and all other matters regarding requirements for degrees.

MASTER OF SCIENCE DEGREE

The Master of Science degree is awarded at North Carolina State after a student has completed a course of study in a specialized field in agriculture and life sciences, education, engineering, forestry, physical sciences and applied mathematics, or textiles; has demonstrated his ability to read a modern foreign language; has completed a satisfactory thesis, and taken comprehensive examinations in the chosen field of study.

In addition to complying with these requirements, the candidate for the Master of Science degree is expected to achieve high levels of scholarship. Graduate study is distinguished from undergraduate work by its emphasis upon independent research. The graduate student is more interested in the significance of facts than in the accumulation of data. He is concerned with the materials of learning and the organization and interpretation of these materials.

A graduate student's program of study is planned so as to provide a comprehensive view of some major field of interest and to

furnish the training essential for successful research in this field and related areas of knowledge. As great a latitude is permitted in the selection of courses as is compatible with a well-defined major interest. The program of course work is selected with the object of making possible a reasonable mastery of the subject matter in a specialized field. Training in research is provided to familiarize the student with the methods, ideals, and goals of independent investigation. Since there are many possible combinations of courses, the administration of graduate programs calls for personal supervision of each student's plan of work by a special advisory committee of the graduate faculty. (See page 30). The program of course work to be followed by the student as part of the requirements for the master's degree, and the thesis problem selected, must be approved by the student's advisory committee and the Dean of the Graduate School.

Credits

1. For the Master of Science degree a minimum of 30 semester credits is required.
2. No more than six of the academic credits required for the degree will be accepted from other institutions.
3. No graduate credit will be awarded for excess undergraduate credit from another institution.
4. All work credited toward a master's degree must be completed within six calendar years.
5. No graduate credit is allowed for courses taken by correspondence. A maximum of six semester credits may be obtained in extension study in the field of education, provided the extension courses are taught by a member of the graduate faculty and provided the courses are given graduate ranking by the Graduate School. Courses taken by extension are accepted for graduate credit only when the student has been admitted to the Graduate School and when notice of his registration is filed with the Graduate Office. Credit for extension courses reduces the amount of credit that may be transferred from other institutions by the amount of graduate credit granted.

The thirty semester credit hour requirement for the master's degree represents the minimum quantity of work acceptable. The credit hours required of graduate students usually exceed the minimum requirements. Inadequate preparation and thesis research frequently make additional work necessary.

Courses of Study

The program of the student shall include at least eight semester credits in courses of the 600 group, no more than six of which may be allowed for research study. At least twenty semester hours must come from the 500 and 600 group. A maximum of two hours of seminar is permitted.

During the first term in residence an advisory committee of at least three faculty members, one representing the minor field, will be appointed by the dean, after consultation with the head of the major department, for each student engaged in a program of work leading to the master's degree. The advisory committee will meet with the student and prepare a program of course work to meet the requirements of the student's graduate objectives. Four copies of the program, prepared on forms provided for this purpose, must be approved by each member of the committee, by the head of the major department, and by the Dean of the Graduate School. After approval in the Graduate Office, three copies will be returned to the department head—one for his files, one for the chairman of the advisory committee, and one for the student.

The courses taken by a graduate student shall constitute a well rounded but unified plan of study. This means that the program of research and course work shall be divided between a major and a minor field. While there are no inflexible rules which govern the number of credit hours that must constitute the major and minor, in general, it is expected that approximately two-thirds of the course work will fall in the major and one-third in the minor. The detailed course requirements for each graduate student program are left to the judgment of the advisory committee.

Residence

Students engaged in a course of study leading to the Master of Science degree are required to be in residence, pursuing graduate work, one full academic year.

Class Work

A graduate student is expected to show greater initiative in exploring the possibilities of the subject matter presented in the courses he takes than is the undergraduate. He is also expected to recognize the significance of facts and to assume a responsibility for relating data to theoretical concepts. In preparation, attendance, and in all the routine of class work the graduate student is subject to the regulations observed in other divisions of the University.

Grades

A minimum grade of "C" must be made on all formal course work to obtain graduate credit. An average of "B" must be obtained on all course work taken as part of the student's graduate program. Failure to maintain a "B" average will place the student on probation. Any student whose academic record fails to meet the "B" average requirement for two consecutive terms will not be permitted to continue a graduate program without the written approval of the graduate dean.

Grades in research, seminar, and special problems courses are

given in terms of "S" (satisfactory) or "U" (unsatisfactory) in place of the symbols used for formal course work.

The grade *incomplete* may be used in research and laboratory courses when circumstances beyond the control of the student have prevented completion of the work by the end of the academic term. A grade of *incomplete* may be given only after approval of the graduate dean and must be converted to one of the usual symbols before the end of the next academic semester in which the student is in residence.

Language Requirements

A reading knowledge of at least one modern foreign language (Germanic, Romance, or Slavic) is required of candidates for the Master of Science degree.

The language requirement must be satisfied before a student can be admitted to candidacy.

Proficiency in languages is determined by the Department of Modern Languages:

1. By traditional reading knowledge examination at any time requested by the student.
2. By taking course work (audit) especially designed for graduate students who have no previous foreign language experience or who wish to refresh work formerly done. The department offers special courses beginning with elementary grammar and proceeding, during the semester, to general scientific reading. Pronunciation is emphasized to the degree in which it will help in translating from the language into English. This first course is followed by a second course in which the student selects work from scientific publications touching as nearly as possible his major interest. He will then be assigned a particular instructor with whom he will read in individual conferences. When the conference instructor is satisfied that the student has demonstrated his knowledge of intricate grammatical problems, a decrease in the time required for reading, and a confidence in his ability to use the language, he will be certified without further examination. The completed translations may then, depending upon their merit, be edited and prepared for permanent filing with the various translation libraries throughout the country.

Graduate students who expect to complete the requirements for the Master of Science degree should confer with the head of the Department of Modern Languages soon after registration to formulate plans for meeting the language requirement of this degree.

Students whose native language is other than English may meet the foreign language requirement for the Master of Science degree by demonstrating a satisfactory mastery of English. Examinations in English are conducted by the Department of Modern Languages.

Thesis

A candidate for the Master of Science degree must prepare a thesis representing an original investigation. The subject of the thesis must be approved by the head of the department in which the major work is done and by the student's advisory committee. Three copies of the thesis in final form, and five copies of the abstract, must be filed in the Graduate Office at least one month before the degree is awarded. Detailed instructions as to form and organization of the thesis may be obtained at the Graduate Office.

Examinations

All candidates for the Master of Science degree must pass, with a grade of "A", "B", or "C", all formal course work specified as part of the requirements for the degree. Graduate credit for research, seminar, and special problems courses is granted when a grade of "S" is recorded in the Registration Office. In addition, the candidate must pass a comprehensive oral examination that is held to satisfy the examining committee that the candidate possesses a reasonable mastery of knowledge in the major and minor fields and that this knowledge can be used with promptness and accuracy. This examination may not be held until all other requirements, except completing the course work of the last semester, are satisfied. Application for the comprehensive oral examination must be filed with the graduate dean by the chairman of the advisory committee at least two weeks prior to the date on which the examination is to be held.

The oral examination will be conducted by an examining committee appointed by the graduate dean. The chairman of the examining committee will be the chairman of the student's advisory committee. At least two additional members will be appointed to represent the major and minor fields. The comprehensive oral examination is open to all faculty members who care to attend but the decision as to the candidate's fitness rests solely with the examining committee.

At the discretion of the examining committee, written examinations covering the subject matter in the major and minor fields also may be required of the candidate. Written examinations, when required, may not be held earlier than the end of the first month of the last semester in residence, and not later than one week before the comprehensive oral examination. See Summary of Procedures for the Master's Degree below.

MASTER'S DEGREE IN A PROFESSIONAL FIELD

This degree is offered for students who are interested in the more advanced applications of fundamental principles to specialized fields rather than in the acquisition of the broader background in advanced scientific studies which would fit them for careers in re-

search. Students working for this degree ordinarily will terminate their graduate work at this point.

Examples of the types of degrees that may be awarded upon completion of the course of study in a professional field are Master of Education, Master of Forestry, Master of Agricultural Engineering, Master of Applied Mathematics, Master of Experimental Statistics, Master of Electrical Engineering, and Master of Textile Technology.

The chief characteristic of these degrees is that the changes made in requirements permit, in greater measure, the satisfaction of what are represented as professional needs than do the requirements for the conventional Master of Science degree.

Language Requirements

The candidate for a master's degree in a professional field is exempt from the requirement of a reading knowledge of a modern foreign language.

Thesis Requirements

In the School of Education the thesis requirement for the master's degree in each of the specialized fields may be waived by the department in which the degree is sought. When the thesis requirement is waived the student must complete the course "Introduction to Educational Research," or a departmental course in research and a problem report. A thesis is not required in the Master of Forestry, Master of Applied Mathematics, Master of Experimental Statistics, Master of Electrical Engineering and Master of Textile Technology programs, nor for professional degrees in the departments of the School of Agriculture and Life Sciences.

Other Requirements

The other requirements for the master's degree in a professional field are the same as for the Master of Science degree.

MASTER OF AGRICULTURE DEGREE

This plan is offered for students interested in advanced training in the broad field of agriculture but whose responsibility is not in research. The requirements for the degree are designed to provide an opportunity for professional training without narrow specialization for those who plan to devote their lives to some phase of practical agriculture. Among the individuals interested in this degree are agricultural extension workers and foreign students who are in action or educational programs. The proposed plan differs from the plan for the Master of Science degree in the following principal respects:

1. A total of thirty-six semester credits is required.
2. A minimum of four semester credits in special problems is

required. Not more than six semester credits in special problems will be allowed. This work replaces the research thesis requirement for the Master of Science degree.

3. There are no specific requirements as to courses in the 600 group.
4. A reading knowledge of a modern foreign language is not required.

In all other respects the requirements for the Master of Agriculture degree are the same as those for the Master of Science degree.

SUMMARY OF PROCEDURES FOR THE PROFESSIONAL MASTER'S DEGREE

1. Letter of inquiry from prospective student to Graduate School or department head.
2. Mailing of proper forms to student by Graduate School or department head.
3. Receipt of application forms and transcripts by Graduate School.
4. Application with transcript sent to department head for study.
5. Department head recommends acceptance of prospective student stating curriculum in which he will work and the degree sought.
6. Assuming the prospective student meets the minimum scholastic standards, notice of acceptance is mailed to him by the Graduate School. When the student's academic record fails to meet the minimum scholastic standards of the Graduate School, provisional admission may be granted upon submission by the student of evidence of a satisfactory performance on the Graduate Record or National Teacher Examination. The National Teacher Examination is accepted only when approved by the department head and the graduate dean.
7. Permit to register is sent by the Graduate School to the registrar.
8. Student arrives, reports to the department head, is assigned an advisor and makes out a roster of courses in consultation with departmental advisor.
9. Advisory committee of three or more faculty members, one of whom represents the minor field, appointed before the end of the first semester of graduate study by the Graduate School after consultation with the department head. If departmental written examinations are required by the major department, then there may be a minimum of two members on the advisory committee (one from the major field and one from the minor).
10. Plan of work prepared by the advisory committee in consultation with the student and submitted in quadruplicate to the Graduate School by the end of the first semester in residence.
11. Plan of work approved by the graduate dean and three copies

returned to the department head. One copy is kept in department files, one goes to the advisor, and one is given to the student. Students preparing themselves for the professional degree in specialized fields of education should consult the chairman of their committees with reference to their problem report.

12. Student applies for admission to candidacy for the master's degree. Application must be filed before the end of the first week of the last semester in residence.
13. Application is reviewed by the head of the major department and by the graduate dean and, if approved, the student becomes a candidate for the degree.
14. Permission for the candidate to take the final oral examination is requested of the Graduate School at least two weeks before the examination.
15. Permission is granted by the graduate dean—date is set and examining committee appointed. The report on the final examination should be filed with the Graduate School as soon as the examination has been completed.
16. Graduate School certifies to the Registration Office and to the Administrative Board of the Graduate School that all requirements for the degree have been met and recommends the awarding of the degree.
17. All requirements must be completed within six calendar years.
18. Student must be registered in semester or session in which degree is to be awarded.

SUMMARY OF PROCEDURES FOR THE MASTER OF SCIENCE DEGREE

1. Letter of inquiry from prospective student to Graduate School or department head.
2. Mailing of proper forms to student by Graduate School or department head.
3. Receipt of application form and transcript by Graduate School.
4. Application with transcript sent to department head for study.
5. Department head recommends acceptance of prospective student stating curriculum in which he will work and the degree sought.
6. Assuming the prospective student meets the minimum scholastic standards, notice of acceptance is mailed to him by the Graduate School. When the student's academic record fails to meet the minimum scholastic standards of the Graduate School, provisional admission may be granted upon submission by the student of evidence of a satisfactory performance on the Graduate Record or National Teacher Examinations. The National Teacher Examination is accepted only when approved by the department head and the graduate dean.
7. Permit to register is sent by the Graduate School to the registrar.
8. Student arrives, reports to the department head, is assigned an

advisor and makes out a roster of courses in consultation with department advisor.

9. Advisory committee of three or more faculty members, one of whom represents the minor field, appointed before the end of the first semester of graduate study by the Graduate School after consultation with the department head.
10. Plan of work prepared by the advisory committee in consultation with the student and submitted in quadruplicate to the Graduate School by the end of the first semester in residence.
11. Plan of work approved by the graduate dean and three copies returned to the department head. One copy is kept in department files, one goes to the advisor, and one is given to the student.
12. A thesis subject is selected and an outline of the proposed research submitted to the department head and to the student's advisory committee.
13. Student passes language examination. The language requirement must be satisfied before admission to candidacy can be granted.
14. Student applies for admission to candidacy for the master's degree. Application must be filed before the end of the first week of the last semester in residence and may not be filed before the language requirement is satisfied.
15. Application is reviewed by the head of the major department and by the graduate dean and, if approved, the student becomes a candidate for the degree.
16. A copy of a preliminary draft of the thesis is submitted to the chairman of the student's committee for criticism.
17. At least two weeks prior to the final oral examination, the chairman of the student's advisory committee submits a corrected draft of the dissertation to members for review.
18. Permission for the candidate to take the final oral examination is requested of the Graduate School at least two weeks before the examination, and must be accompanied by a certification that the thesis is complete except for such revisions as may be necessary as a result of the final examination.
19. Permission is granted by the graduate dean—date is set and examining committee appointed. The report on the final examination should be filed with the Graduate School as soon as the examination has been completed.
20. Three copies of the thesis in final form approved by each member of the student's advisory committee and signed by the advisor must be submitted to the Graduate School at least four weeks before the end of the semester or summer session in which the degree is to be conferred.
21. Graduate School certifies to the registration office and to the general faculty that all requirements for the degree have been met and recommends the awarding of the degree.

22. All requirements must be completed within six calendar years.
23. Student must be registered in term in which degree is to be awarded.

DOCTOR OF PHILOSOPHY DEGREE

The degree of Doctor of Philosophy is offered in the following fields of study:

Animal Science
Applied Mathematics
Biochemistry
Biological and Agricultural Engineering
Botany (in the fields of physiology and ecology)
Chemical Engineering
Chemistry
Civil Engineering
Crop Science
Economics
Electrical Engineering
Engineering Mechanics
Entomology
Experimental Statistics
Food Science
Forestry
Genetics
Mechanical Engineering
Microbiology
Mineral Industries (in the field of ceramic engineering)
Nuclear Engineering
Physics
Physiology
Plant Pathology
Rural Sociology
Soil Science
Wood Science and Technology
Zoology

The doctor's degree symbolizes the fact that the recipient is capable of undertaking original research and scholarly work at the highest levels without supervision. Therefore, the Doctor of Philosophy degree is not granted on the basis of successful completion of a given amount of course work, but rather upon the demonstration by the candidate of a comprehensive knowledge and high attainment in scholarship and research in a specialized field of study. These attainments are determined by the quality of the dissertation which the candidate prepares to report the results of original investigations and by passing successfully a series of rigorous and comprehensive examinations on the special and related fields of study.

Course of Study

At the time of admission the student should, with the advice of the chairman of the department, elect a major field. During the student's first semester in residence, an advisory committee of at least four members will be appointed by the graduate dean, after consultation with the department head, to prepare with the student a plan of graduate work. Four copies of the program, signed by all members of the advisory committee and the department head or graduate administrator, are referred to the graduate dean for approval. When approved, three copies are returned to the department head, one being retained in the department files, a second copy is given to the chairman of the advisory committee, and the third copy is given to the student. The subject of the dissertation must appear on the plan of work and any subsequent changes in the subject of the thesis or in the plan of graduate work must be reported to the Graduate School for approval.

There are no definite requirements in credit hours for the doctor's degree. Emphasis is placed upon a comprehensive knowledge of a well defined and recognized field and related subjects. Each student will have a major and one or two minor areas of specialization. The minor field ordinarily will consist of at least twenty semester credit hours. These may fall in an allied department or in the major department. A minor in the department of the major is permitted only when the department offers recognized divisions of study other than that designated as the major field.

Residence

For the Doctor of Philosophy degree, the student is expected to be registered for graduate work for at least six semesters beyond the bachelor's degree at some accredited graduate school. The amount of work from other institutions credited to the fulfillment of degree requirements will be determined by the dean after consultation with the student's advisory committee at the time the plan of graduate work is filed.

At least two residence credits, as defined below, must be secured in continuous residence (registration in consecutive semesters) as a graduate student at some branch of the consolidated University of North Carolina. Failure to take work during the summer does not break the continuity; however, summer school work can be used to fulfill this requirement.

Residence credit is based on the number of credits of graduate work beyond the bachelor's degree carried in a given term. During a regular semester, residence credit is calculated in the following manner:

Semester Credits	*Residence Credits*
9 or more	1
6 - 8	⅔
less than six*	⅓

* Including registration for thesis preparation on campus.

The residence credit for a six-week summer term is only one-half the corresponding amount for a regular semester; i.e., six semester credits carry 1/3 residence credit and less than six credits, 1/6 residence credit. If a student registers for a twelve-week summer term, the residence credit is computed as for regular semesters. If a student registers for both twelve-week and six-week summer terms, the residence credit is computed separately for each type and totaled, with the stipulation that no more than one residence credit can be earned in a given summer.

The candidate must complete all requirements for the degree, including the final examination on his dissertation, within a period of seven calendar years from the date of admission to candidacy for the degree.

Languages

A reading knowledge of scientific literature in two modern foreign languages or a comprehension in depth of one language is required for the Doctor of Philosophy degree.

Comprehension in depth is to be interpreted as a proven ability in the oral and composition elements of a particular language as well as the reading knowledge normally required. Ph.D. students desiring to offer one language in depth should consult with the head of the Department of Modern Languages as to the specific courses to be followed to achieve this comprehension. Specific arrangements may differ, depending upon the student's previous background in the language. It is emphasized that students choosing to achieve competence in depth in one language will generally find this alternative more rigorous than proof of reading ability in two languages.

If the student elects to work in two languages, the languages may be a combination of Romance and Slavic, Romance and Germanic, or Slavic and Germanic.

Students whose native tongue is some language other than English may use English as one of the languages required for the Doctor of Philosophy degree. When English is submitted in partial fulfillment of the language requirements, the native language may not be used to satisfy one of the language requirements.

The Dissertation

The doctoral dissertation presents the results of the candidate's original investigations in the field of his major interest. It must represent a contribution to knowledge, adequately supported by data and written in a manner consistent with high standards of excellence in scholarship. Detailed instructions relating to the thesis may be obtained from the Graduate Office.

Publication of the results obtained in the thesis investigation is expected. Each copy of the thesis must be accompanied by an abstract of approximately 500 words.

The dissertation will be examined by all members of the examin-

ing committee and must receive their approval to be acceptable to the Graduate Office.

Two copies of the dissertation in final form, signed by all members of the student's advisory committee, and five copies of the abstract must be presented to the Graduate School not later than four weeks before the date on which the degree is to be awarded.

North Carolina State now has an agreement with University Microfilms, Inc., of Ann Arbor, Michigan, by which all doctoral dissertations are microfilmed and abstracts of the dissertations are published in Dissertation Abstracts.

Examinations

Not earlier than the end of the second year of graduate study and not later than the midpoint of the semester immediately preceding that in which the degree is expected, each doctoral student is required to pass general comprehensive examinations (known as the qualifying or preliminary examinations). If summer sessions are involved, the two consecutive summer sessions are, for these purposes, considered as equivalent to one semester. The examinations are given by an examining committee of graduate faculty members appointed by the graduate dean after consultation with the head of the department in which the student's major work has been taken. The examining committee usually consists of the student's advisory committee and a representative of the Graduate School, but may include other members of the graduate faculty. The examinations are open to all members of the graduate faculty who may care to attend.

Authorization for the qualifying examination is requested of the Graduate School by the chairman of the student's advisory committee when the major part of the student's program of course work has been completed and when, in judgment of the committee, the student is prepared to devote the greater part of his time to the prosecution of his research study. Members of the examining committee will be notified of their appointment by the Graduate Office. Official printed forms will be supplied to the chairman of the examining committee for a report of the results of the examination.

The examination consists of two parts: (1) written examinations and (2) an oral examination held before the entire examining committee. When, in the judgment of the chairman of the student's advisory committee the student is ready for the written examinations, arrangements may be made. Two approaches are acceptable. In the first, the chairman requests examination questions from each member of the examining committee. Each set of questions is given to the student by the chairman in any order that may seem appropriate. The questions, together with the student's answers, are then returned to the members of the committee for grading. This procedure is still used by departments having a relatively small number of doctoral candidates. Many of the larger departments, however,

have found it impractical to have separate written examinations prepared by each student's committee and have instituted departmental written examinations to be used for all candidates. These examinations are given several times during the year and scheduled dates are announced well in advance. Where written departmental examinations of this kind are made available, the student majoring or minoring in the field of the department will be expected to make arrangements for taking these examinations. Questions on written examinations may cover any phase of the course work taken by the student during the period of his graduate study or any subject logically related and basic to an understanding of the subject matter of the major and minor areas of study. They should be designed to measure the student's mastery of these subject matter fields and the adequacy of his preparation for research investigations.

Upon satisfactory completion of the written examinations the student must pass an oral examination before the entire examining committee. This examination is usually held within a week after the chairman of the examining committee has certified to the Graduate School that the student has completed satisfactorily the written examinations. The members of the examining committee will be notified by the Graduate School of the time and place arranged for the oral examination. The oral examination is designed to test the student's ability to relate factual knowledge to specific circumstances. In the oral examination the student is expected to use his knowledge with accuracy and promptness and to demonstrate that his thinking is not limited to the facts learned in course work.

A unanimous vote of approval is required for passing the preliminary examination. Approval may be conditioned, however, upon the completion of additional work in some particular field to the satisfaction of the committee. In case a single dissenting vote is cast, the course of action to be taken will become a matter for decision by the Administrative Board. Upon receiving the approval of the examining committee the student is admitted to candidacy for the doctorate.

A final oral examination is also required. During a normal academic year, an interval of at least eight months must elapse between admission to candidacy and the final oral examination. If summer sessions are involved, this interval may be interpreted to include two consecutive summer sessions and one academic semester.

This examination is held after the dissertation has been completed, and consists of a defense by the candidate of the methods used and the conclusions reached in his research study. The examination is conducted by an examining committee. The examining committee usually includes the student's advisory committee, plus a representative of the Graduate School, although this procedure is not always adopted. The examining committee is appointed by the graduate dean after consultation with the head of the student's major department.

Failure of a student to pass either the preliminary or the final

examination terminates his graduate work at this institution unless otherwise recommended by the examining committee. No re-examination may be given until at least one full semester has elapsed since the first examination. Only one re-examination is permitted.

See Summary of Procedures for Doctor of Philosophy Degree below.

Admission to Candidacy

A student is admitted to candidacy after he has successfully passed the preliminary examinations. The language requirements must be fulfilled before permission to take the preliminary examination is granted. Admission to candidacy must be obtained not later than the midpoint of the semester immediately preceding that in which the degree is expected.

Additional Information

A booklet containing detailed instruction about the form of the dissertation may be obtained from the Graduate School.

Further information concerning graduate work at North Carolina State University may be secured from *Dr. Walter J. Peterson, Dean of the Graduate School, North Carolina State University at Raleigh, Raleigh, North Carolina.*

SUMMARY OF PROCEDURES FOR THE DOCTOR OF PHILOSOPHY DEGREE

1. Letter of inquiry from prospective student to Graduate School or department head.
2. Mailing of proper forms to student by Graduate School or department head.
3. Receipt of application forms by Graduate School.
4. Application with transcript sent to department head for study.
5. Department head recommends acceptance of prospective student stating curriculum in which he will work.
6. Assuming the prospective student meets the minimum scholastic standards, notice of acceptance is mailed to him by the Graduate School.
7. Permit to register is sent by Graduate School to the registrar.
8. Student arrives, reports to the department head, is assigned an advisor, and makes out a roster of courses in consultation with departmental advisor.
9. Advisory committee of at least four members is appointed in the first term of graduate study by the graduate dean after consultation with the department head.
10. Plan of work is prepared by the advisory committee in consultation with the student and submitted in quadruplicate to the Graduate School by the end of the first semester in residence.
11. Plan of work is approved by the graduate dean and three copies

returned to the department head. One copy is kept in department files, one goes to the advisor, and one is given to the student.

12. A dissertation subject is selected and an outline of the proposed research submitted to the department head and the student's advisory committee.
13. Student passes language examinations.
14. When the student has completed satisfactorily all the courses in the minor field on his plan of work, he may, with the consent of the chairman of his committee, take the written qualifying examination in the field of his minor. If desirable, this examination may be taken if all but one of the courses in the minor field have been completed and the student is taking the last such course during the semester in which the examination is held. The results of this examination will be reported to the Graduate School. The examination in the minor field may be combined with the examination in the major field.
15. The written examination in the major field may be scheduled upon approval of the Dean of the Graduate School not earlier than the end of the second year of graduate study and not later than the mid-point of the semester immediately preceding that in which the degree is expected. The results of this examination will be reported to the Graduate School.
16. When all written examinations have been completed satisfactorily, the oral qualifying examination may be held. The Graduate School is notified one week in advance of the time and place of this examination. The report of the examination is sent to the Graduate School. If the report is favorable, the student is admitted to candidacy.
17. A copy of the preliminary draft of the dissertation is submitted to the chairman of the student's committee for criticism.
18. At least two weeks prior to the final oral examination, the chairman of the student's advisory committee submits a corrected draft of the dissertation to members for review.
19. Eight months (or two terms) after admission to candidacy or later, permission for the candidate to take the final oral examination is requested of the Graduate School by the chairman of the candidate's advisory committee. Requests should be filed at least two weeks before the date of the examination and must be accompanied by a certification that the thesis is complete except for such revisions as may be necessary as a result of the final examination.
20. Permission is granted by the graduate dean if the student's record is in order. A date is set and examining committee appointed. The report on the examination should be filed with the Graduate School as soon as examination has been completed.
21. Two copies of the thesis in final form and five copies of the abstract must be submitted to the Graduate School not later than four weeks before the date on which the degree is to be

awarded. It must carry the signatures of all members of the examining committee.

22. Graduate School certifies to the Registration Office and to the general faculty that all requirements for the degree have been met and recommends the awarding of the degree.
23. All requirements must be completed within seven calendar years from date of admission to candidacy for the doctoral degree.
24. Student must be registered in the term in which the degree is to be awarded.

The Erdahl-Cloyd Union is the center for many student activities, including concerts, lectures and exhibits. The Union sponsored concert series is among the best attended in the United States.

FIELDS OF INSTRUCTION

Departmental Announcements and Description of Courses

The course descriptions are planned for the academic years 1966-67 and 1967-68, unless indicated otherwise. Specific courses may not be offered, however, if registration for a course is too low, or if faculty or facilities are not available.

Courses in the 500 series are open to seniors and graduate students. All courses in this series carry full graduate credit. Courses in the 600 series are open to graduate students only. Master's programs must include not less than 20 semester hours from courses in the 500 and 600 series.

DEPARTMENT OF ADULT EDUCATION

GRADUATE FACULTY

Professor: EDGAR JOHN BOONE, *Head*

Associate Professors: ROBERT JOHN DOLAN, EMILY H. QUINN

The Department of Adult Education offers programs of study leading to the Master of Adult Education and Master of Science degrees with a major in adult education.

The program is based upon an interdisciplinary approach and is designed to provide graduate students the opportunity to develop a broad and comprehensive understanding of adult education and a high level of professional competence in conducting research. Bolstering the interdisciplinary base of the graduate program is the Graduate Institute of Adult Education, administered by an Administrative Board, which includes the deans of the Schools of Agriculture and Life Sciences, Education, Liberal Arts, and the Graduate School at North Carolina State University, and the dean of the School of Home Economics at the University of North Carolina at Greensboro.

A candidate for the master's degree must acquire a comprehensive understanding of the adult and society, and the theories of learning, social action, group processes, communication and planning requisite to effecting change among people. While a basic comprehension of these relevant theories is the first essential, the candidate must also understand their interrelationships and how they apply to adult education. The degree candidate must present a thesis based on his own research.

The basic aspects of the behavioral sciences as related to adult education is the central theme of the Department of Adult Education's graduate program. The varied but coordinated interests of the department's faculty with their research programs offer a variety of opportunities for graduate student training that is found in few institutions.

The Department of Adult Education is housed in Ricks Hall. It

has a modern and well-equipped department library including all major professional journals in adult education and the behavioral sciences.

Courses for Graduates and Advanced Undergraduates

Ed 501 See SOC 501, LEADERSHIP. 3(3-0) s

ED 502 See PS 502, PUBLIC ADMINISTRATION. 3(3-0) s

ED 503 THE PROGRAMMING PROCESS IN ADULT EDUCATION 3(3-0) fs
Prerequisites: ED 501, permission of instructor

The principles and processes involved in programming, including basic theories and concepts supporting the programming process. Attention will be given to the general framework in which programming is done, the organization needed, and the program roles of both professional and lay leaders. Messrs. Boone, Dolan

ED 513 See RS 513, COMMUNITY ORGANIZATION. 3 (3-0) s

ED 559 PRINCIPLES OF ADULT EDUCATION 3(3-0) s
Prerequisite: Six hours in education

Principles involved in adult education programs including theories and concepts undergirding and requisite to these programs. Emphasis will be given to the interrelationship of the nature of adult learning, the nature of the subject matter and the setting in which learning occurs. The applicability of relevant principles and pertinent research findings to adult learning will be thoroughly treated. Mrs. Quinn

ED 596 TOPICAL PROBLEMS IN ADULT EDUCATION Credits by Arrangement

Study and scientific analysis of problems in adult education, and preparation of a scholarly research type of paper. Graduate Staff

Courses for Graduates Only

ED 696 SEMINAR IN ADULT EDUCATION 1(1-0) f

Identification and scientific analysis of major issues and problems relevant to adult education. Credit for this course will involve the active participation of the student in a formal seminar and the scientific appraisal and solution of a selected problem. The course is designed to help the student acquire a broad perspective of issues confronting adult educators and to acquire experience in the scientific analysis and solution of specific issues. Graduate Staff

DEPARTMENT OF AGRICULTURAL EDUCATION

GRADUATE FACULTY

Professors: CLARENCE CAYCE SCARBOROUGH, *Head*, JAMES BRYANT KIRKLAND

Associate Professors: HARRY GEDDIE BEARD, LAWRENCE WILLIAM DRABICK

Assistant Professors: CHARLES DOUGLAS BRYANT, TEXTON ROBERT MILLER

The Department of Agricultural Education offers programs of study leading to the Master of Science and the Master of Education degrees. Graduate programs are designed to meet the needs of the individual student for further study and research as well as for the role of local educational leader. All programs emphasize research. As part of the

graduate program, each student must complete a thesis or a research problem.

In addition to the many resources available to all North Carolina State graduate students, agricultural education students have available assistance from administrative and supervisory staff members of the State Department of Public Instruction in Raleigh.

A number of graduate assistantships are available. Preference is given to experienced educational leaders in agricultural education.

Courses for Graduates and Advanced Undergraduates

ED 554 Planning Programs in Agricultural Education 3 (3-0) s
Prerequisite: ED 411 or equivalent

Analysis of theory of planning and change. Consideration of the need for planning programs in agricultural education; objectives and evaluation of community programs; use of advisory groups; organization and use of facilities; role of the leader. Messrs. Bryant, Scarborough

ED 568 Adult Education in Agriculture 3 (3-0) fs
Prerequisite: ED 411 or equivalent

Designed to meet the needs of leaders in adult education. Opportunity to study some of the basic problems and values in working with adult groups. Particular attention will be given to the leadership role in educational programs for adults. Messrs. Bryant, Scarborough

ED 593 Special Problems Credits by Arrangement
Prerequisite: ED 411 or equivalent

Opportunities for students to study current problems under the guidance of the staff. Graduate Staff

Courses for Graduates Only

ED 617 Philosophy of Agricultural Education 3 (3-0) s
Prerequisite: ED 554 or equivalent

An examination of educational philosophies and their relation to current educational programs in agricultural education. Mr. Scarborough

ED 664 Supervision in Agricultural Education 3 (3-0) f
Prerequisite: ED 563 or equivalent

Organization, administration, evaluation and possible improvement of supervisory practice; theory, principles and techniques of effective supervision in agricultural education at different levels. Mr. Scarborough

ED 693 Advanced Problems Credits by Arrangement
Prerequisite: ED 593 or equivalent

Study of current and advanced problems in the teaching and administration of educational programs, evaluation of procedures and consideration for improving. Graduate Staff

ED 694 Seminar in Agricultural Education 1 (1-0) fs

A critical review of current problems, articles, and books of interest to students of agricultural education. Graduate Staff

DEPARTMENT OF ANIMAL SCIENCE

GRADUATE FACULTY

Professors: Ira Deward Porterfield, *Head,* Elliott Roy Barrick, Edward Guy Batte, Lemuel Goode, George Hyatt, Jr., James Giacomo Lecce, James Edward Legates, Gennard Matrone, Harold Arch Ramsey,

FRANK HOUSTON SMITH, HAMILTON ARLO STEWART, SAMUEL B. TOVE, LESTER CURTIS ULBERG, GEORGE HERMAN WISE, MILTON B. WISE

Associate Professors: ALBERT J. CLAWSON, EMMETT URCEY DILLARD, RICHARD DOUGLAS MOCHRIE, ODIS WAYNE ROBISON

Assistant Professors: EDWARD VITANGELO CARUOLO, DONALD GOULD DAVENPORT, EUGENE J. EISEN, JAMES MURRAY LEATHERWOOD, JOHN JOSEPH MCNEILL, RICHARD MONIER MYERS, ALLEN HUFF RAKES

The Department of Animal Science offers programs leading to the degrees of Master of Science and Doctor of Philosophy in three sections (Animal Breeding, Animal Diseases, and Nutrition) that are functionally oriented, and in two sections (Animal Husbandry and Dairy Husbandry) that are commodity oriented. The interrelationships among these sections are such that a student who chooses any one benefits from close association with the others. The goals of all are to provide programs of interest and challenge, offering students opportunities to develop creative ability to the degree that they will have the knowledge and the motivation to contribute constructively in their chosen profession and in closely related fields.

The availability of a variety of modern laboratories, specialized equipment, and experimental subjects enables the student to become familiar with the tools of research and their use in expanding knowledge in the various segments of animal science. The research exposure in fulfilling the requirements for degrees, more than any other single factor, determines the specialization characteristics in animal science.

Students in the Animal Breeding Section concentrate on problems pertaining to efficient utilization of superior germ plasm. Emphasis is given to quantative genetics and reproductive physiology. Experimental subjects include not only livestock but also small animals. Among the facilities is a laboratory building designed and used to study various factors affecting reproduction.

Students in the Animal Disease Section may specialize in pathology, parasitology, veterinary bacteriology, virology or other phases of animal disease. For research and training in these areas, a modern building including appropriate laboratories and equipment is provided.

Students in the Nutrition Section are trained primarily in the fundamental aspects of the science of this field. Programs are oriented toward the basic phases of nutrition, including metabolism of minerals, lipids, higher carbohydrates, proteins, and microbes; physiology and biochemistry of digestion; and biochemical evaluation of nutrient sources. Excellent laboratory facilities, biochemical and animal, are available.

Students in the Animal Husbandry Section may select problems in nutrition, developmental physiology, carcass quality, production efficiency and interrelationships of breeding, and feeding and management of species of livestock classified as meat animals.

Students in the Dairy Husbandry Section have the option of nutrition, physiology or management of dairy cattle for major emphasis in their programs.

In both of the husbandry sections, livestock, farms, feeding facilities, and laboratories are such that a variety of problems may be used effectively in graduate programs.

Strong collateral support through course offerings and research cooperation is available in the areas of biochemistry, physiology, genetics, microbiology, statistics, economics, sciences, and food sciences. Therefore, graduate programs in animal science offer opportunities for the multi-dimensional development of students.

Courses for Advanced Undergraduates

ANS 404 Dairy Farm Problems 3 (2-3) s
Prerequisite: ANS 201

Advanced study of practical dairy farm management including farm records, farm buildings, sanitation, roughage utilization and herd culling.

ANS 407 Advanced Livestock Production 3 (3-0) s
Prerequisites: GN 411, ANS 312

A study of the economic, nutritional, genetic, physiological and managerial factors affecting the operation of commercial and purebred livestock enterprises.

ANS 408 Reproduction and Lactation 3 (2-3) s
Prerequisite: ZO 421

Anatomy of the reproductive organs and mammary glands with detailed coverage of the physiological processes involved and of factors controlling and influencing them. A special research problem selected by the student is required.

ANS 409 Advanced Livestock Production Lab 1 (0-3) s
Prerequisites: GN 411, ANS 312

A study of the economic, nutritional, genetic, physiological and managerial factors affecting the operation of commercial and purebred livestock enterprises. Laboratory.

ANS 490 Animal Science Seminar 1 (1-0) s

Review and discussion of special topics and the current literature pertaining to all phases of animal production.

Courses for Graduates and Advanced Undergraduates

ANS 503 (GN 503) Genetic Improvement of Livestock and Poultry 3 (2-3) f
Prerequisite: GN 411 or equivalent

The application of genetic principles to the economic improvement of animal agriculture. Phenotypic and genetic relationships among economic traits as well as mode of inheritance and method of measurement of the traits. The role of inbreeding, outbreeding and selection methods in producing superior genetic populations. Mr. Robinson

ANS 505 Diseases of Farm Animals 3 (3-0) f
Prerequisites: CH 101, CH 103

The pathology of bacterial, viral, parasitic, nutritional, thermal and mechanical diseases processes. Mr. Batte

ANS 513 Needs and Utilization of Nutrients by Livestock 3 (3-0) s
Prerequisite: ANS 312 or equivalent

Measurement of nutrient needs of livestock and the nutrient values of feeds. Nutritive requirements for productive functions. Mr. Wise

ANS 590 Topical Problems in Animal Science Maximum 6 fs
Special problems may be selected or assigned in various phases of animal science. Graduate Staff

Courses for Graduates Only

ANS 603 (GN 603) Population Genetics in Animal Improvement 3 (3-0) f
Prerequisites: ST 512, GN 512
A study of the forces influencing gene frequencies, inbreeding and its effects, and alternative breeding plans. Mr. Legates

ANS 604 (ZO 604) Experimental Animal Physiology 4 (2-4) f
Prerequisite: ZO 513 or equivalent
A study of the theories and techniques involved in the use of animals in physiological investigation. Messrs. Ulberg, Wise

ANS 614 (BO 614) Bacterial Metabolism 2 (2-0) s
Prerequisites: BO 514 or equivalent, CH 551
The energy metabolism of bacteria; synthesis of carbohydrates, lipids, proteins, purines, pyrimidines, and nucleic acids; bacterial photosynthesis; enzyme formation and metabolic control mechanisms. Mr. McNeill

ANS 622 (ST 622) Principles of Biological Assays 3 (3-0) s
Prerequisites: CH 551, ST 512
Techniques and designs of biological assays. The interrelationship of logical principles, designs, and analyses is emphasized. Staff

ANS 653 (BCH 653) Mineral Metabolism 3 (3-0) s
Prerequisite: CH 551
Principles of mineral metabolism, with emphasis on metabolic functions, reaction mechanisms and interrelationships. Mr. Matrone

ANS 655 (BCH 655) Intermediary Metabolism I 3 (3-0) s
Prerequisites: CH 551 and permission of instructor
A study of carbohydrate, lipid, and energy metabolism. Mr. Tove

ANS 690 Seminar in Animal Nutrition 1 (1-0) fs
Prerequisite: Permission of seminar leaders
Orientation in philosophy of research, preparation for research and general research methodology. Graduate Staff

ANS 699 Research in Animal Science Credits by Arrangement
A maximum of six hours is allowed toward the master's degree; no limitation on credits in doctorate program. Graduate Staff

DEPARTMENT OF BIOCHEMISTRY

GRADUATE FACULTY

Professors: Gennard Matrone, *Acting Head*, Leonard William Aurand,* Ian S. Longmuir, Samuel B. Tove

Adjunct Professor: Monroe Eliot Wall

Associate Professors: Frank Bradley Armstrong, Samuel G. Levine,* Alexander Russell Main, Edward Carroll Sisler

Assistant Professors: Horace Robert Horton, Joseph Stephan Kahn

The field of biochemistry applies and extends the concepts of chemistry and physics to the investigation of biological problems. The

* Affiliated Graduate Faculty Member

Department of Biochemistry offers courses of study leading to the degrees of Master of Science and Doctor of Philosophy.

A student entering into graduate study in biochemistry should have a bachelor's degree in chemistry or a biological science. The undergraduate program of studies should include two semesters of organic chemistry, one of quantitative analysis, and two semesters of physical chemistry. Students who lack undergraduate courses considered essential for graduate study in biochemistry may be admitted to the graduate program; however, appropriate course work to make up academic deficiencies must be successfully completed early in their graduate studies.

Courses in General Biochemistry (BCH 551) and Intermediary Metabolism (BCH 655 and 657) are required as part of the program leading to advanced degrees (majors and minors) in biochemistry.

In addition to completing a program of studies approved by his advisory committee, a candidate for an advanced degree in biochemistry is expected to participate regularly in biochemistry seminars throughout his graduate residence, and to engage in independent research leading to the completion of a scholarly thesis. Research programs are currently being conducted in biochemical genetics, enzyme structure and mechanisms, inhibition kinetics, biochemical aspects of toxicology, biochemical control mechanisms, photosynthesis developmental biochemistry of plants, methylation reactions in plants, lipid metabolism, volatile fatty acid metabolism, biochemical role of copper, metal ion interactions *in vivo* and *in vitro*, and oxygen transport mechanisms.

Courses for Graduates and Advanced Undergraduates

BCH 551 General Biochemistry I 3 (3-0) f
Prerequisites: CH 231 or CH 431 or permission of instructor; physical chemistry strongly recommended

Principles of modern biochemistry, including a study of structural and metabolic relationships of carbohydrates, lipids, proteins, nucleic acids, enzymes, and coenzymes. Mr. Longmuir

BCH 555 Plant Chemistry 3 (2-3) s
Prerequisite: BCH 551

Composition of plants; properties, nature, and classification of plant constituents; changes occurring during growth, ripening, and storage of plant products. Mr. Sisler

BCH 561 (GN 561, MB 561) Biochemical and Microbial Genetics 3 (3-0) f
Prerequisites: BCH 551, GN 411 or 512, and MB 401, or equivalent

A study of the development of the fields of biochemical genetics and microbial genetics, emphasizing both techniques and concepts currently used in research in these areas. Includes lectures and discussions of current research publications. Mr. Armstrong

Courses for Graduates Only

BCH 651 (BO 651) Physical Biochemistry 3 (3-0) s
Prerequisite: CH 433

Structural and physical properties of proteins and other macromolecules; photochemistry of biological systems. Mr. Armstrong

BCH 652 Biochemical Research Techniques 3 (1-8) s
Prerequisites: BCH 551; CH 215 or CH 411

Instrumentation and techniques for separation, identification, and characterization of biochemical constituents; laboratory methods of isolation, assay, and characterization of enzymes; kinetics of enzyme catalyzed reactions. Mr. Horton, Staff

BCH 653 (ANS 653) Mineral Metabolism 3 (3-0) f
Prerequisite: BCH 551

Principles of mineral metabolism with emphasis on metabolic functions, reaction mechanisms, and interrelationships. Mr. Matrone

BCH 655 (ANS 655) Intermediary Metabolism I 3 (3-0) s
Prerequisite: BCH 551

A study of carbohydrate, lipid, and energy metabolism. Mr. Tove

BCH 657 Intermediary Metabolism II 3 (3-0) f
Prerequisite: BCH 551

A study of amino acid, protein, and nucleic acid metabolism, including lectures and discussions of current research publications. Mr. Horton

BCH 659 (CH 659) Natural Products 3 (3-0) f
Prerequisite: CH 521

Synthetic and degradative procedures and conformational analysis in naturally occurring compounds. Mr. Levine

BCH 691 Seminar in Biochemistry Credit by Arrangement
Graduate Staff

BCH 695 Special Topics in Biochemistry Credit by Arrangement
Prerequisites: BCH 551, BCH 655, BCH 657

Critical study of special problems in modern biochemistry.
Graduate Staff

BCH 699 Biochemical Research Credit by Arrangement
Graduate Staff

DEPARTMENT OF BIOLOGICAL AND AGRICULTURAL ENGINEERING

GRADUATE FACULTY

Professors: Francis Jefferson Hassler, *Head*, Henry Dittimus Bowen, William Eldon Splinter

Professor Emeritus: David S. Weaver

Associate Professors: William Hugh Johnson, Kenneth Allan Jordan, Charles Wilson Suggs

Assistant Professors: James William Dickens, Barney Kuo-Yen Huang, Ervin Grigg Humphries, David Alan Link, Cliff R. Willey, Ralph E. Williamson, Edward H. Wiser

The Department of Biological and Agricultural Engineering offers programs of study for the Master of Science, Doctor of Philosophy and Master of Agricultural Engineering degrees. A bachelor's degree in agricultural engineering from an accredited curriculum or its equivalent entitles an individual to one of two approaches to graduate study. For those primarily interested in existing technologies, the Master of Agricultural Engineering program permits selections from a variety of advanced technical courses. Such study is appropriate to certain

supervisory and managerial positions, technical sales, service and promotional work.

The Master of Science program takes into account the increasing rigor of modern engineering. Emphasis here is on mathematics and theory as the unifying link between otherwise widely divergent fields of knowledge which are prerequisite to effective engineering advances in agricultural production. As the student acquires competence in the advanced methods of science, he derives mathematical models for reduction of observational knowledge to engineering applications.

Study for the Doctor of Philosophy degree builds on the Master of Science program by an additional year of formal study followed by a period of independent research to satisfy dissertation requirements.

Unusual opportunities are available for graduate student participation in departmental research programs. Current projects include: Animal Environment; Watershed Hydrology, Drainage and Irrigation; Crop Processing and Materials Handling; Field Production Operations; Fruit and Vegetable Mechanization; Pesticide Applications; Human Engineering; and Operations Research. The systems approach to operations in crop and animal production provides a variety of areas within which to define timely investigations.

Graduate students have access to a research shop, manned by competent mechanics.

Information concerning fellowships and assistantships in biological and agricultural engineering may be obtained from the head of the department.

Courses for Advanced Undergraduates

BAE 411 Farm Power and Machinery 3 (2-3) fs
Prerequisite: BAE 211, PY 211 or PY 221

This course is designed to provide students in agricultural engineering technology with a knowledge of the operations of manufacturing and distribution organizations of farm machinery and their places in these organizations. Included is a practical course in farm tractors and engines with emphasis on familiarizing the student with component parts—their application, operation, and maintenance, as well as with the selection of these units from the standpoint of power, performance, and ratings.

Mr. Fore

BAE 433 Crop Preservation and Processing 3 (2-3) s
Prerequisite: PY 211

This course deals with the physical and biochemical characteristics of harvested crops and crop products, as they define the requirements for the best preservation of quality. The properties of air-water vapor mixtures, the application of heat to air and crops, the characteristics and use of fans and heaters, the air flow requirements and measurement for crop preservation and materials handling will be studied. Feed preparation, mixing and handling are included in the course. Mr. Weaver

BAE 453 Bioengineering Parameters 2 (2-0) f
Prerequisites: BAE 303, BAE 352, MA 301

Physical properties and response characteristics of plant materials are studied in their relationship to engineering analysis for production, harvesting and processing operations. Topics include germination, growth

dynamics, physical properties for harvesting and materials handling, biological response criteria, environmental effects, theory of curing and drying, and quality evaluation. Mr. Johnson

BAE 461 Analysis of Agricultural Production Systems 3 (3-0) f
Prerequisites: MA 201, EC 205, ST 361

Survey of methods of systems analysis for agricultural engineering students. Intermediate economic analysis, with particular emphasis on farm machinery economics; materials-handling problems; activity network and scheduling problems; techniques of obtaining and processing systems data. Mr. Link

BAE 462 Functional Design of Field Machines 3 (2-2) s
Prerequisites: BAE 361, ME 301, BAE 461, SSC 200

A study of the modern farm tractor and field machines. The emphasis of the course is on the translation of measurements of biological and physical factors of the agricultural production system into machine specifications that can be effectively converted into production machines by engineers of the manufacturing industry. Mr. Bowen

BAE 471 Soil and Water Conservation Engineering 3 (2-3) s
Prerequisites: CE 201, SSC 200, ST 361

General aspects of agricultural hydrology, including precipitation, classification of climate, rainfall disposition, methods of estimating runoff, fundamental soil and water relationships, and hydraulics of flow in open channels and closed conduits, will be given. Included also are factors affecting erosion, methods of controlling erosion, land use classification, drainage, land clearing, irrigation methods, design requirements for portable irrigation systems, and economic aspects of irrigation in the Southeast. Mr. Wiser

BAE 481 Design of Farmstead Engineering Systems 3 (2-3) s
Prerequisites: BAE 453, BAE 461, BAE 491

Application of conditioning principles to provide the required environment for optimum agricultural production is stressed. Environmental requirements imposed by the biological materials in farmstead systems are related to the first principles of physiology. Consideration of labor reduction and replacement of human decisions with control mechanisms are formalized. Environmental requirements, proper arrangement, material flow, equipment selection and control, and estimation of external loads are presented to indicate design procedures for a sound, functional building. Mr. Jordan

BAE 491 Electrotechnology for Agricultural Production 3 (2-3) f
Prerequisites: EE 331, EE 332

Principles of operation of sensors and transducers and their use in measuring environmental and physical variables. Typical circuits will be used to illustrate how sensing devices are employed, to illustrate the use of circuit analysis techniques, and to study the operational characteristics. Control circuits with applications of transient analysis for environment control and switching circuits for materials handling systems. Relevant power distribution techniques, wiring codes, and power machinery will be studied in relation to agricultural production problems. Mr. McClure

Courses for Graduates and Advanced Undergraduates

BAE 552 Instrumentation for Agricultural Research and Processing 2(1-3) f
Prerequisites: EE 331, MA 301

Theory and application of primary sensing elements and transducers. Calibration and use of standards. Use of electronic and solid state circuits

in amplifiers, recorders and controllers. Special circuits for agricultural processing. Mr. Splinter

BAE 590 Special Problems Credits by Arrangement
Prerequisite: Senior or graduate standing

Each student will select a subject on which he will do research and write a technical report on his results. He may choose a subject pertaining to his particular interest in any area of study in agricultural engineering.
Graduate Staff

Courses for Graduates Only

BAE 654 Agricultural Process Engineering 3 (3-0) s
Prerequisite: MA 441

Generalized classical thermodynamics is extended by Onsager's relations to provide a theoretical basis for analyzing the energetics of systems that include life processes. Mr. Johnson

BAE 661 Analysis of Function and Design of Farm Machinery 3 (2-3) s
Prerequisite: PY 411

Studies of methods and equipment used in determining the functional requirements of machine components and the writing of machine specifications in terms of fundamental parameters. A study of the principles of descriminate and indescriminate mechanical selection of agricultural products with emphasis on the theory of servo-systems. (Offered 1965-66 and alternate years.) Mr. Bowen

BAE 671 Theory of Drainage, Irrigation and Erosion Control 4 (4-0) s
Prerequisite: MA 513

Emphasis is placed on the physical and mathematical aspects of problems in conservation engineering and an attempt is made to rationalize procedures which have often come about through experience rather than through analytical consideration. Examples are presented of cases where such an analytical approach has already improved, or shows promise of improving, design criteria and procedures. Mr. Kriz

BAE 681 Analysis of Function and Design of Farmstead Systems 4 (4-0) f or s
Prerequisite: BAE 481

A study of the parameters in the design of a farmstead system with economic criteria pertaining to a formal design procedure. Mr. Jordan

BAE 695 Seminar 1 (1-0) fs
Prerequisite: Graduate standing in agricultural engineering
A maximum of two credits is allowed.

Elaboration of the subject areas, techniques and methods peculiar to professional interest through presentations of personal and published works; opportunity for students to present and defend, critically, ideas, concepts and inferences. Discussions to point up analytical solutions and analogies between problems in agricultural engineering and other technologies, and to present the relationship of agricultural engineering to the socioeconomic enterprise. Mr. Hassler

BAE 699 Research in Agricultural Engineering
Credits by Arrangement
Prerequisite: Graduate standing in agricultural engineering
A maximum of six credits is allowed toward a master's degree; no limitation on credits for doctorate program.

Performance of a particular investigation of concern to agricultural engineering. The study will begin with the selection of a problem and culminate with the presentation of a thesis. Graduate Staff

DEPARTMENT OF BOTANY

GRADUATE FACULTY

Professors: GLENN RAY NOGGLE, *Head*, DONALD BENTON ANDERSON, ERNEST A. BALL, ERNEST OSCAR BEAL, ROBERT JACK DOWNS, HERBERT TEMPLE SCOFIELD, LARRY ALSTON WHITFORD

Visiting Professor: GEORGE JOHN SCHUMACHER

Professor Emeritus: BERTRAM WHITTIER WELLS

Associate Professors: ARTHUR WELLS COOPER, JAMES WALKER HARDIN, JAMES RICHARD TROYER

Assistant Professors: ROGER C. FITES, JOSEPH STEPHAN KAHN, ROYALL TYLER MOORE, HAROLD EDWARD PATTEE, HEINZ SELTMANN, RALPH EDWARD WILLIAMSON

Associate Members of the Department of Botany

Professors: CLARENCE LESLIE MCCOMBS, DONALD EDWIN MORELAND

The Department of Botany offers programs leading to the Master of Science and Doctor of Philosophy degrees with major emphases in the areas of plant physiology, ecology, anatomy, morphology, mycology, phycology, and systematic botany.

Excellent physical facilities and equipment are available for teaching and research in all phases of the department's program. Controlled environment growth rooms, greenhouse facilities and field plots are readily accessible. The use of radioisotopes in physiological, phycological, and morphological research is supported by adequate facilities. The department maintains an electron microscope for teaching and research purposes. A fine herbarium supports study in systematics and ecology. The availability in North Carolina of a wide range of habitats with an accompanying diversity of flora provides opportunities for research problems in ecology, mycology, phycology, and systematics.

Graduate students terminating their work at the master's level have a number of opportunities available for employment in state, federal, and industrial laboratories. Academic positions are also available in junior colleges, as well as in certain four-year colleges. Holders of the Doctor of Philosophy degree will find opportunities for academic positions in colleges and universities, for research positions in federal and state experiment stations, and for research and development work with private industrial research institutions.

Courses for Advanced Undergraduates

BO 403 SYSTEMATIC BOTANY 4 (2-4) s
Prerequisite: BS 100

A systematic survey of vascular plants emphasizing field identification, terminology, and general evolutionary relationships. Mr. Hardin

BO 421 PLANT PHYSIOLOGY 4 (3-3) fs
Prerequisites: BS 100 and one year of college chemistry

Physiology of the green plant emphasizing plant organization, water and solute relationships, organic and inorganic nutrition, growth and development.

BO 442 (ZO 442) General Ecology 4 (3-3) f
Prerequisite: BS 100

The general principles of the interrelationships among organisms and between organisms and their environment—land, fresh-water, and marine.
Messrs. Cooper, Quay, Standaert

BO 486 (CE 486) Weather and Climate 2 (2-0) f
Prerequisites: MA 102 or MA 112, PY 211-212 or PY 221

A discussion of basic principles of meteorology and climatology. Topics discussed include the atmosphere, radiation, moisture, pressure and wind, atmospheric equilibrium, air masses and fronts. Macro- and micro-climate and the climate of North Carolina are also covered.
Messrs. Cooper, Carney

Courses for Graduates and Advanced Undergraduates

BO 512 Morphology of Vascular Plants 3 (1-6) f
Prerequisite: BS 100

A study of comparative morphology, ontogeny and evolution of the vascular plants. Emphasis is placed upon the phylogeny of sexual reproduction and of the vascular systems.
Mr. Ball

BO 513 Plant Anatomy 3 (1-6) s
Prerequisite: BS 100

A study of the anatomy of the Angiosperms and Gymnosperms. The development of tissues is traced from their origin by meristems to their mature states.
Mr. Ball

BO 522 Advanced Systematics of Angiosperms 4 (3-3) f
Prerequisite: BO 403

A comprehensive survey of the systematics and evolution of angiosperm families. Special emphasis is given to detailed morphology, phylogeny, and critical identification in laboratory and field. (Offered 1965-66 and alternate years.)
Mr. Hardin

BO 544 Plant Geography 3 (3-0) s
Prerequisites: BO 403, BO 442, GN 411 or equivalents

A course in descriptive and interpretive plant geography, synthesizing data from the fields of ecology, genetics, geography, paleobotany, and taxonomy. Includes a survey of the present distribution of major vegetation types throughout the world, a discussion of the history and development of this present pattern of vegetation, and a discussion of the principles and theories of plant geography. (Offered in 1966-67 and alternate years.)
Mr. Cooper

BO 545 Advanced Plant Ecology 3 (2-3) s
Prerequisites: BO 421, BO 442 or equivalents

An advanced consideration, through class discussions and individual projects, of the principles, theories, and methods of plant ecology. (Offered in 1965-66 and alternate years.)
Mr. Cooper

BO 574 (MB 574) Phycology 3 (1-4) s
Prerequisite: BS 100

An introduction to the structure, reproduction and importance of the classes of organisms which may be included in the algae. Considerable time is devoted to the local fresh-water and marine floras and the ecology of important species.
Mr. Whitford

BO 575 (MB 575, PP 575) The Fungi 4 (3-3) s
Prerequisite: BO 301 or equivalent

An overview of the fungi within the framework of a survey of the major classes. Lectures, while covering the major groups systematically, will

also include ancillary material such as aspects of ultrastructure, environmental adaptions, sexuality, ontogeny, and economic, including historical, importance. Laboratory sessions will provide for study of both known and unknown material to familiarize the student with the characteristics of the fungi and to develop an appreciation of the problems and methods of their classification. Mr. Moore

BO 588 (ZO 588) Cell Physiology 3 (3-0) s
Prerequisites: BO 421 or ZO 421 and permission of instructor

A study of fundamental physiological properties at the cellular level with emphasis on basic principles. Messrs. Roberts, Troyer

BO 589 (ZO 589) Cell Physiology Laboratory 1 (0-3) s
Prerequisites: BO 588 (ZO 588) (may be taken concurrently) and permission of instructor

Experimental approaches in the study of physiological processes at the cellular level. Attention will be devoted to the theoretical usefulness of laboratory techniques along with their practical limitations.
Messrs. Roberts, Troyer

BO 590 Topical Problems 1 to 3 fs
Prerequisite: Permission of instructor

Discussions and readings on problems of current interest in the fields of ecology, anatomy and morphology, taxonomy, and cell biology. May be repeated with change in topic for a maximum of six credits.
Graduate Staff

Courses for Graduates Only

BO 620 Advanced Taxonomy 3 (2-2) f
Prerequisites: BO 522 and permission of instructor

A course in the principles of plant taxonomy including the history of taxonomy, systems of classification, rules of nomenclature, taxonomic literature, taxonomic and biosystematic methods, and monographic techniques. (Offered 1966-67 and alternate years.) Mr. Hardin

BO 632 Plant Nutrition 3 (3-0) f
Prerequisite: BO 588

An advanced course in plant physiology covering the subcellular organization of plants, photosynthesis, inorganic and organic metabolism, and respiration. Mr. Noggle

BO 633 Plant Growth and Development 3 (3-0) s
Prerequisite: BO 588

An advanced course in plant physiology covering plant growth, development, differentiation, senescence, and biological control mechanisms.
Mr. Fites

BO 636 Discussions in Plant Physiology 1 (1-0) fs
Prerequisite: BO 588

Group discussions at an advanced level of selected topics of current interest in plant physiology. Graduate Staff

BO 691 Botany Seminar 1 (1-0) fs

Scientific articles, progress reports in research, and special problems of interest to botanists are reviewed and discussed. Graduate student credit is allowed if one paper per semester is presented at seminar.
Graduate Staff

BO 693 Special Problems in Botany Credits by Arrangement

Directed research in some specialized phase of botany other than a thesis problem but designed to provide experience and training in research.
Graduate Staff

BO 699 RESEARCH Credits by Arrangement
Original research preliminary to writing a master's thesis or a doctoral dissertation. Graduate Staff

CERAMIC ENGINEERING

(For a listing of graduate faculty and departmental information see Department of Mineral Industries, page 159.)

Courses for Advanced Undergraduates

MIC 415, 416 CERAMIC ENGINEERING DESIGN 3 (1-5) fs
Prerequisites: MIC 306, EM 301

A two-semester study to encourage creative solutions to problems of current interest and need in the ceramic profession. Discussion of sources of data, design principles, creativity, optimization, economic value analysis and decision making. Individual and team study involving interdependence of plant layout, processes, equipment and materials in the design of engineering systems or sub-systems. Study of factors in utilization of ceramics in materials systems.

MIC 430 RESEARCH AND CONTROL METHODS 3 (2-3) f
Prerequisite: MIC 306

Interpretation of results, instrumental methods applied to research and product development. Statistical quality control.

MIC 431 REACTION KINETICS IN CERAMIC SYSTEMS 4 (3-3) s
Prerequisites: MIM 201, CH 431

A study of reactions taking place during thermal treatment of ceramic systems. Such topics as thermodynamics, heterogeneous phase equilibria, diffusion, solid state reactions, nucleation and grain growth are treated.

MIC 432 PRINCIPLES OF THE GLASSY PHASE 4 (3-3) f
Prerequisite: MIC 431

A study of the glassy state to include the structure, properties, and types of glasses (including glazes and enamels). Opacity, color, and devitrification. Nature of the glassy phase in kiln fired ceramics.

MIC 433 CERAMIC MICROSTRUCTURE AND PROPERTIES 4 (3-3) s
Prerequisite: MIC 431

A study of the properties and behavior of processed ceramics from the standpoint of their phase characterization, atomic, micro-and macro-structure. Characteristics of ceramics are interpreted in terms of basic mechanisms affecting thermal, electronic, magnetic, mechanical, optical and nuclear properties. Emphasis is placed on process treatment and environmental effects.

MIC 451 PRINCIPLES OF CERAMIC ENGINEERING 3 (3-0) f
Prerequisite: CH 433 or ME 302 or CHE 315

An advanced treatment of fundamental relationships among ceramic materials, processes, and properties. Designed to provide an adequate background for students from other engineering and physical science curricula to permit effective study of ceramic engineering at the graduate level. Lecture.

MIC 491 SEMINAR 1 (1-0) fs
One semester required of seniors in ceramic engineering; a second semester may be elected.

Literature survey of selected topics in ceramic engineering. Oral and written reports, discussions.

Courses for Graduates and Advanced Undergraduates

MIC 501, 502 Ceramic Structural Analysis 3 (3-0) fs
Prerequisite: MIG 331

Basic laws of crystal structures. Arrangement of ions in crystals. Estimation of phases present in multi-component systems utilizing x-ray techniques. Analysis of glass structure. Correlation of structure with composition and properties. Mr. Hamme

MIC 503 Ceramic Microscopy 3 (2-3) f
Prerequisite: MIG 331

Transmitted and reflected light techniques for the systematic study of ceramic materials and products. Interpretation and representation of results. Mr. Hackler

MIC 506 Electron Microscopy 3 (2-3) f
Prerequisite: MIC 503 or PY 404 or EE 507

The theory of the realization of electrostatic and magnetic lenses for electron microscopy. Major emphasis is placed on interpretation of electron diffraction and surface replications of ceramics and metals. Mr. Lucier

MIC 509 High Vacuum Technology 3 (2-3) summer
Prerequisite: CH 433 or ME 301

Properties of low pressure gases and vapors. Production, maintenance, and measurement of high vacuum; design, construction, and operation of high vacuum, high temperature facilities. Properties and reactions of materials which are processed, tested, and/or utilized in high vacuum enrivonments. Mr. Palmour

MIC 527 Refractories in Service 3 (3-0) s
Prerequisite: CH 433

A study of the physical and chemical properties of the more important refractories in respect to their environment in industrial and laboratory furnaces. Mr. Kriegel

MIC 529 Properties of High Temperature Materials 3 (3-0) s
Prerequisite: MIM 201

Effect of temperature on the physical, mechanical and chemical properties of inorganic materials; relationships between microstructure and high temperature properties; uses of ceramics, cermets, and metals at extremely high temperatures. Mr. Stoops

MIC 533, 534 Advanced Ceramic Engineering Design 3 (2-3) fs
Prerequisites: MIC 416, MIC 433

Advanced studies in analysis and design of ceramic products, processes, and systems leading to original solutions of current industrial problems and the development of new concepts of manufacturing. Mr. Palmour

MIC 540 Glass Technology 3 (3-0) f
Prerequisite: MIC 432

Fundamentals of glass manufacture including compositions, properties and application of the principal types of commercial glasses.
Mr. Kriegel

MIC 548 Technology of Cements 3 (3-0) s
Prerequisite: MIC 431

The technology of the Portland cement industry including manufacture, control and uses. Mr. Kriegel

MIC 596, 597 Advanced Ceramic Experiments 3 (1-6) fs
Prerequisite: MIC 430 or equivalent

Advanced studies in ceramic laboratory experimentation.
Graduate Staff

Courses for Graduates Only

MIC 601 Ceramic Phase Relationships 3 (3-0) s
Prerequisite: Permission of instructor

Heterogeneous equilibrium, phase transformations, dissociation, fusion, lattice energy, defect structure, thermodynamic properties of ionic phases and silicate melts. Mr. Hackler

MIC 603 Advanced Ceramic Reaction Kinetics 3 (3-0) s
Prerequisites: MIC 431, MIC 501

Fundamental study of the kinetics of high temperature ceramic reactions such as diffusion, nucleation, grain growth, recrystalization, phase transformation, vitrification and sintering. Mr. Stoops

MIC 611 Ceramic Process Analysis 3 (3-0) f
Prerequisite: MIC 502
Corequisite: ST 516

Analysis of experimental and production data for ceramic processes. Quantitative evaluation of the effect of materials, materials preparation, heat distribution, composition, and other variables on properties. Sampling from production. Linear programming to compound glass and cement batches. Mr. Hackler

MIC 621 The Vitreous State 3 (3-0) s
Prerequisite: MIC 540

An advanced study of the structure of binary and ternary silicate and borate glasses. Influence of structure on properties of vitreous systems. Mr. Hackler

MIC 631, 632 Advanced Physical Ceramics I, II 3 (2-3) fs
Corequisites: MIC 501, MIC 502 or MIM 521, MIM 522, EM 501, EM 502 or PY 503, PY 552

Lattice structures and lattice energies in crystalline ceramics; relationships with elastic, optical, and thermal properties. Effects of constitution and microstructure on lattice-sensitive properties. The defect crystalline state in ceramics: vacancies, color centers, dislocations, boundaries. Crystal growth. Plastic deformation processes, including creep and fatigue; the ductile-brittle transition. Structure-sensitive properties of crystalline, vitreous and composite ceramics; effects of constitution, microstructure, non-stoichiometry. Mr. Palmour

MIC 635, 636 Electronic Ceramics 3 (3-0) summer
Prerequisites: MA 441 and PY 407 or PY 414 or EE 531

Lattice energy, dielectric and optical properties of insulators, ferroelectrics, magnetic oxides, electron distribution in insulators and semiconductors; electronic properties of alkali halides. Mr. Stadelmaier

MIC 695 Ceramic Engineering Seminar 1 (1-0) fs

Reports and discussion of special topics in ceramic engineering and allied fields. Graduate Staff

MIC 697 Special Studies in Ceramic Engineering 1 to 3 credits

Special studies of advanced topics in ceramic engineering. Credit will vary with the topic. Graduate Staff

MIC 699 Ceramic Research Credits by Arrangement

An original and independent investigation in ceramic engineering. A report of such an investigation is required as a graduate thesis. Graduate Staff

DEPARTMENT OF CHEMICAL ENGINEERING

GRADUATE FACULTY

Professors: EDWARD MARTIN SCHOENBORN, *Head*, RICHARD BRIGHT, JAMES K. FERRELL, KENNETH ORION BEATTY, JR.

Visiting Professor: WARREN LEE MCCABE

Associate Professors: DAVID BOYD MARSLAND, FRANCES MARIAN RICHARDSON, JOHN FRANK SEELY

Assistant Professor: EDWARD PAUL STAHEL

Adjunct Assistant Professor: ROBIN PIERCE GARDNER

The Department of Chemical Engineering offers programs of advanced study and research leading to the Master of Science and Doctor of Philosophy degrees. The Chemical Engineering faculty seeks to provide a close association between faculty and students, to promote a common interest in advanced professional study, and to encourage intensive investigation and top-level creative activity.

Graduate work in chemical engineering is of increasing importance since it enables the student to attain a higher degree of specialized professional competence and at the same time to secure greater mastery of the sciences underlying the quantitative aspects of chemical technology. The demand for chemical engineers with advanced training is greater now than at any time since the beginning of the chemical industry.

Students with one or more years of training beyond the baccalaureate are especially needed for fundamental and applied research, process development and design, production, and even for management, technical service and sales. Consulting work and careers in teaching usually demand a period of advanced study well beyond the normal four-year undergraduate program.

At present, major emphasis in the department is concerned with basic studies of unit operations such as fluid flow, heat transfer at high and low temperatures, mass transfer distillation, and solvent extraction, with thermodynamics, reaction kinetics, phase equalibria, plastics technology, process measurement and control and many other aspects of chemical technology. The varied interests of an exceptionally well-qualified staff provide guidance for advanced study in any phase of chemical engineering. Strong supporting programs are available in mathematics, statistics, physics, chemistry, nuclear engineering, metallurgy, the life sciences, textiles, and other fields of engineering.

The Department of Chemical Engineering occupies the four-story east wing of the Riddick Engineering Laboratories building. Modern, well-equipped laboratories are provided with all necessary services for both teaching and research. A wide variety of special facilities such as analog and digital computers, X-ray equipment, spectrophotometers, electron microscope, electromechanical testing machine, electronic controllers and recorders are available for graduate research.

In cooperation with the Department of Engineering Research, mem-

bers of the chemical engineering staff conduct a number of important research projects which are supported by industry, state, and federal agencies. Graduate students assisting on these projects not only acquire financial assistance but gain valuable research experience on problems of current interest.

In addition to research assistantships, the department offers each year a limited number of graduate assistantships for part-time work in the department. These may be for teaching, laboratory preparation, or research, as the need arises. Appointments are for one academic year of nine months for half-time work and, at present, carry a stipend of $2,700 renewable upon evidence of satisfactory performance.

Courses for Advanced Undergraduates

CHE 421, 422 Reactor Energy Transfer I, II 3 (3-0) fs
Prerequisites: MA 202, PY 208

Thermodynamics, heat transfer and fluid flow with emphasis on the problems and methods used in the design and analysis of nuclear reactors.

CHE 425 Process Measurement and Control 3 (2-2) f
Prerequisite: CHE 312
Required of seniors in chemical engineering.

Theory and application of methods for measuring, recording, transmitting and controlling process variables. The techniques of analysis, beginning with process elements in automatic control and proceeding through systems analysis, are employed. Analog and digital computers are used in the study and solution of problems.

CHE 427, CHE 428 Separation Processes I, II 3 (3-0) fs
Prerequisite: CHE 311
Required of seniors in chemical engineering.

A study of the principles underlying such unit operations as absorption, extraction, distillation, drying, filtration, etc., with emphasis on procedures and economic considerations.

CHE 431 Chemical Engineering Laboratory I 2 (0-6) s
Prerequisite: CHE 311
Required of juniors in chemical engineering.

Laboratory work on typical apparatus involving unit operations. Experiments are designed to augment the theory and data of lecture courses and to develop proficiency in the writing of technical reports.

CHE 432, 433 Chemical Engineering Laboratory II, III 2 (0-6) fs
Prerequisites: CHE 312, CHE 427
Required of seniors in chemical engineering.

A continuation of CHE 431.

CHE 446 Chemical Process Kinetics 3 (3-0) s
Prerequisite: CHE 315
Required of seniors in chemical engineering.

A basic study of homogeneous and heterogeneous chemical reactions, and of catalysis.

CHE 495 Seminar 1 (1-0) fs
One semester required of seniors in chemical engineering.

Professional aspects of chemical engineering; topics of current interest in chemical engineering.

CHE 497 Chemical Engineering Projects 2 (0-6) fs
Elective for seniors in chemical engineering.

Introduction to research through experimental, theoretical and literature studies of chemical engineering problems. Oral and written presentation of reports.

Courses for Graduates and Advanced Undergraduates

CHE 511 Problem Analysis for Chemical Engineers 3 (3-0) s
Prerequisites: CHE 428, MA 301

The application of the methods of mathematical analysis to the formulation and solution of problems in transport phenomena, transient phenomena in unit operations, process dynamics, and thermodynamics. Study and use of analog computer solutions of these problems. Mr. Ferrell

CHE 513 Thermodynamics I 3 (3-0) f
Prerequisite: CHE 315 or equivalent

An intermediate course in thermodynamic principles and their application to chemical and phase equilibria. The course is largely from a macroscopic viewpoint but consideration will be given to some aspects of the statistical viewpoint. Mr. Beatty

CHE 515 Transport Phenomena 3 (3-0) s
Prerequisite: CHE 312

A theoretical study of transport of momentum, energy, and matter with emphasis on the latter two. The diffusional operations, including coupled heat and mass transfer, are introduced in the light of the theory.
Mr. Marsland

CHE 517 Kinetics and Catalysis 3 (3-0) f
Prerequisite: CHE 446

An intensive study of homogeneous and heterogeneous kinetic reactions. Emphasis will be placed on fundamental approaches, experimental methods, and mathematical techniques in engineering analysis of chemical reaction systems. Mr. Stahel

CHE 540 Electrochemical Engineering 3 (3-0) s
Prerequisite: Physical chemistry

The application of electrochemical principles to such topics as electrolysis, electroanalysis, electroplating, and metal refining. Mr. Schoenborn

CHE 541 Cellulose Industries 3 (3-0) f
Prerequisite: Organic chemistry

Methods of manufacture and application of cellulose chemical conversion products. Emphasis placed on recent developments in the field of synthetic fibers, films, lacquers, and other cellulose compounds. Mr. Seely

CHE 543 Technology of Plastics 3 (3-0) s
Prerequisite: Organic chemistry

The properties, methods of manufacture, and applications of synthetic resins. Recent developments in the field are stressed. Mr. Seely

CHE 551 Thermal Problems in Nuclear Engineering 3 (3-0) s
Prerequisite: ME 302 or ME 303, or CHE 311, or equivalent

The design and operation of nuclear reactors and the utilization of the power from them involves major problems in nearly every phase of heat transfer, and many important problems in fluid flow. Possible solutions to these problems are severely affected by the influences of radiation on heat transfer media, hazards of handling radioactive substances, etc. The course considers the thermal problems of nuclear reactor design and the principles of fluid flow and heat transfer necessary to their solutions. The course is intended for engineers and science students with backgrounds in physics, mathematics, and elementary thermodynamics. Mr. Beatty

CHE 597 Chemical Engineering Projects 1-3 credits fs
Prerequisite or corequisite: CHE 412

A laboratory study of some phase of chemical engineering or allied field. Graduate Staff

Courses for Graduates Only

CHE 610 Heat Transfer 3 (3-0) f
Prerequisite: CHE 515

An advanced course dealing primarily with heat transfer between liquids and solids, optimum operating conditions and design of equipment, conduction, heating and cooling of solids, radiant heat transmission.
Mr. Beatty

CHE 621 Mass-Transfer Operations 3 (3-0) f
Prerequisite: CHE 515

Application of transport theory and empirical devices to the analysis, synthesis and design of mass-transfer equipment. The operations of absorption, extraction, distillation, humidification, and drying will be considered. Mr. Marsland

CHE 622 Chemical Reaction Engineering 3 (3-0) s
Prerequisite: CHE 517

An advanced study of ideal and real reactor systems. The approach employed is twofold: 1. Characterization of actual systems by empirical rate expressions coupled with fundamental analysis; 2. Simulation of coupled physical and chemical processes in a reactor by solution of various types of physical models. Mr. Stahel

CHE 623 Fluid and Particle Dynamics 3 (3-0) s
Prerequisite: CHE 515

The principles of fluid dynamics and their application to laminar and turbulent flow, flow in closed channels, flow in packed beds and porous media, particle technology, industrial rheology, and two-phase flow.
Mr. Ferrell

CHE 624 Process Dynamics 3 (3-0) f
Prerequisite: CHE 511

A detailed study of the dynamic response of typical chemical process equipment including instrumentation and process control devices. Fundamental concepts of automatic control of process variables such as temperature, pressure flow, and liquid level. Mr. Ferrell

CHE 625 Thermodynamics II 3 (3-0) f
Prerequisite: CHE 513

A consideration of various thermodynamic topics of special interest to chemical engineers. The effects of high pressures and high temperatures on equilibria, relationship of thermodynamics to rate process, thermodynamics of the steady state including coupled transfer process, and experimental methods in thermodynamics would be typical. Mr. Beatty

CHE 631 Chemical Process Design 3 (3-0) s
Prerequisite: CHE 428

Design and selection of process equipment, through solution of comprehensive problems involving unit operations, kinetics, thermodynamics, strength of materials and chemistry. Graduate Staff

CHE 690 Readings in Chemical Engineering Credits by Arrangement fs

A comprehensive survey of the literature in a specified area, and an exhaustive survey on a chosen topic within that area, under the direct guidance of the thesis advisor. This course has the goals of (a) mature selection of a research topic, and (b) preparation for a research proposal in fullest possible detail. Graduate Staff

CHE 693 Advanced Topics in Chemical Engineering 1-3 credits fs

A study of recent developments in chemical engineering theory and

practice, such as ion exchange, crystallization, mixing, molecular distillation, hydrogenation, fluorination. The topic will vary from term to term.
Graduate Staff

CHE 695 SEMINAR 1 (1-0) fs
Literature investigations and reports of special topics in chemical engineering and allied fields. Graduate Staff

CHE 699 RESEARCH Credits by Arrangement fs
Independent investigation of an advanced chemical engineering problem. A report of such an investigation is required as a graduate thesis.
Graduate Staff

DEPARTMENT OF CHEMISTRY

GRADUATE FACULTY

Professors: RALPH CLAY SWANN, *Head,* DAVID MARSHALL CATES, GEORGE OSMORE DOAK, LEON DAVID FREEDMAN, RICHARD HENRY LOEPPERT, WALTER JOHN PETERSON, WILLIS ALTON REID, COWIN COOK ROBINSON, HENRY AMES RUTHERFORD, PAUL PORTER SUTTON, RAYMOND CYRUS WHITE

Adjunct Professors: VIVIAN THOMAS STANNETT, MONROE ELIOT WALL

Associate Professors: LAWRENCE HOFFMAN BOWEN, CARL LEE BUMGARDNER, ALONZO FREEMAN COOTS, FORREST WILLIAM GETZEN, CHESTER E. GLEIT, LOUIS ALLMAN JONES, SAMUEL G. LEVINE, GEORGE GILBERT LONG, RICHARD COLEMAN PINKERTON

Assistant Professors: HALBERT H. CARMICHAEL, M. KEITH DEARMOND, FORREST CLYDE HENTZ, JR., MARION L. MILES, CHARLES GLEN MORELAND, WILLIAM PRESTON TUCKER, GEORGE HENRY WAHL, JR.

The Department of Chemistry offers the degrees of Master of Science and Doctor of Philosophy. Students may major in analytical, inorganic, organic, or physical chemistry.

A student entering into graduate work in chemistry should have a bachelor's degree in chemistry or its equivalent. Minimum course requirements include the equivalent of four basic year courses in general, organic, physical, and analytical chemistry, and semester courses in inorganic chemistry and qualitative organic analysis. At least one year of college physics and two years of mathematics, including differential equations, are also required. Students who fail to meet the requirements may in some cases be admitted on a provisional basis.

Some areas of active research in which thesis work may be done include organic and inorganic syntheses, structure and properties of organometallic compounds and transition metal complexes, stereochemistry of natural and synthetic compounds, kinetics and mechanisms of reactions, radiochemistry, electrochemistry, tracer studies, microanalysis, polymer and fiber chemistry, and infrared and nuclear magnetic resonance spectroscopy.

The department is well-equipped with standard instruments and apparatus for research and teaching. Many items of specialized equipment are available, including recording spectrophotometers covering the range from far infrared to ultraviolet, a Varian HA-100 nuclear magnetic resonance spectrometer, temperature-programmed and prep-

arative gas chromatographs, automatic fraction collectors, refrigerated centrifuges, an automatic C,H,N analyzer, microbalances, Mossbauer effect apparatus, and a hydrogen cryostat. The department has particularly well-equipped spectrographic and radiochemical laboratories.

Teaching and research assistantships and fellowships are available for qualified applicants.

Courses for Advanced Undergraduates

CH 401 Systematic Inorganic Chemistry 3 (3-0) s
Corequisite: CH 433

A survey of the chemical elements based on atomic structure and the periodic system, also introducing newer concepts of structure and symmetry. A knowledge of basic physical chemical principles is prerequisite.

CH 411 Analytical Chemistry I 4 (2-6) f
Prerequisites: CH 431, CH 432
Corequisite: CH 433

An introduction to analytical chemistry, including both classical and modern techniques involving the distribution of a component between phases, for example, gravimetric methods, gas chromatography, and adsorption.

CH 413 Analytical Chemistry II 4 (2-6) s
Prerequisite: CH 411

A continuation of Analytical Chemistry I, with emphasis upon modern approaches to acid-base chemistry, oxidation-reduction, potentiometric methods, and spectrophotometry.

CH 428 Qualitative Organic Analysis 3 (1-6) fs
Prerequisite: CH 223

An introduction to the identification of organic compounds by means of physical properties (including infrared spectra), chemical classification tests, and preparation of derivatives.

CH 431 Physical Chemistry I 3 (3-0) fs
Prerequisites: CH 107, MA 202, PY 207 or PY 208

CH 431 and 433 provide an intensive study of the states of matter, solutions, colloids, homogeneous and heterogeneous equilibrium, reaction kinetics, electrolysis, conductance, oxidation reactions, and ionic equilibrium.

CH 432 Physical Chemistry I Laboratory 1 (0-3) f
Corerequisite: CH 431

Laboratory course to accompany the lecture work in CH 431.

CH 433 Physical Chemistry II 3 (3-0) fs
Prerequisite: CH 431

A continuation of CH 431.

CH 434 Physical Chemistry II Laboratory 1 (0-3) s
Corequisite: CH 433

Laboratory course to accompany the lecture work in CH 433.

CH 435 Physical Chemistry III 3 (3-0) f
Prerequisite: CH 433

An intensive study of the structure of atoms and molecules, an introduction to statistical mechanics, and selected topics in modern physical chemistry.

CH 441 Colloid Chemistry 3 (2-3) s
Prerequisites: CH 215, CH 220

Adsorption; preparation, properties, constitution, stability, and application of sols, gels, emulsions, foams, and aerosols; dialysis; Donnan membrane equilibrium.

CH 490 Chemical Preparations 3 (1-6) fs
Prerequisite: Three years of chemistry

Lectures and laboratory work in preparative chemistry. Synthetic procedures will be selected to illustrate advanced methods and techniques in both inorganic and organic chemistry.

CH 491 Reading in Honors Chemistry
2 to 6 Credits by Arrangement fs
Prerequisite: Three years of chemistry

A reading course for exceptionally able students at the senior level. The students will do extensive reading in areas of advanced chemistry and will present written reports of their findings.

CH 493 Chemical Literature 1 (1-0) f
Prerequisite: Three years of chemistry

A systematic introduction to the location and retrieval of information required for the solution of chemical problems.

CH 499 Senior Research 1 to 3 Credits by Arrangement fs
Prerequisite: Three years of chemistry

An introduction to research. Independent investigation of a research problem under the supervision of a member of the chemistry faculty.

Courses for Graduates and Advanced Undergraduates

CH 501 Inorganic Chemistry I 3 (3-0) f
Prerequisite: CH 433

Modern inorganic chemistry from the point of view of the chemical bond. Chemical periodicity and its origins in atomic structure, the ionic bond and electronegativity, crystal structure and bonding in ionic solids, the metallic state, conduction and semi-conductors, and the preparation and properties of illustrative compounds. Mr. Long

CH 503 Inorganic Chemistry II 3 (3-0) s
Prerequisite: CH 501

The hydrogen molecule-ion and the theory of the covalent bond, molecular orbitals and hybridization, dipole moments and magnetic properties, the theory of acids and bases, non-aqueous solvents, coordination compounds, carbonyl and quasiaromatic compounds, and the chemistry of the transition metals, lanthanides, and actinides. Mr. Long

CH 511 Chemical Spectroscopy 3 (2-3) f
Prerequisite: CH 433

Theory, analytical applications, and interpretation of spectra as applied to chemical problems. Major emphasis will be placed upon ultraviolet, visible, and infrared spectra. Messrs. DeArmond, Long

CH 513 Electroanalytical Chemistry 3 (2-3) s
Prerequisite: CH 413

Foundations of theoretical electrochemistry, potentiometric measurements and electrical resistance, diffusion and transport, theory of dilute solutions, polarography and amperometric measurements, surface effects and electrode kinetics, electrochemistry in non-aqueous systems.
Mr. Pinkerton

CH 521 Advanced Organic Chemistry I 3 (3-0) f
Prerequisites: Three years of chemistry including CH 223

Resonance, reaction mechanisms, hydrocarbons, organic halides, alcohols, amines, and carbonyl compounds. Messrs. Doak, Wahl

CH 523 Advanced Organic Chemistry II 3 (3-0) s
Prerequisite: CH 521

Stereochemistry of organic compounds, including steroids and other natural products. Messrs. Doak, Miles

CH 531 Chemical Thermodynamics 3 (3-0) f
Prerequisites: CH 433, MA 301

An extension of elementary principles to the treatment of ideal and real gases, ideal solutions, electrolytic solutions, galvanic cells, surface systems, and irreversible processes. An introduction to statistical thermodynamics and the estimation of thermodynamic functions from spectroscopic data. Mr. Sutton

CH 533 Chemical Kinetics 3 (3-0) s
Prerequisites: CH 433, MA 301

An intensive survey of the basic principles of chemical kinetics with emphasis on experimental and mathematical techniques, elements of the kinetic theory, and theory of the transition state. Applications to gas reactions, reactions in solution, and mechanism studies. Messrs. Bowen, Carmichael

CH 535 Surface Phenomena 3 (3-0) f
Prerequisites: CH 433, MA 301

An intensive survey of the topics of current interest in surface phenomena. Formulations of basic theories are presented together with illustrations of their current applications. Mr. Getzen

CH 537 Quantum Chemistry 3 (3-0) s
Prerequisites: MA 301, CH 433 or PY 407

The elements of wave mechanics applied to stationary energy states and time dependent phenomena. Applications of quantum theory to chemistry, particularly chemical bonds. Mr. Coots

CH 543 Radioisotope Principles and Techniques 3 (2-3) f
Prerequisites: CH 433, PY 207, MA 202

A presentation of the basic principles of radioactivity, nuclear reactions, and radiochemistry essential to competence in the use of radioisotopes. Mr. Coots

CH 545 Radiochemistry 3 (2-3) s
Prerequisites: CH 543, PY 410

The applications of radioactivity to chemistry and of the applications of chemistry to the radioactive elements, particularly the trans-uranium elements and fission products. Mr. Coots

CH 562 (TC 562) Chemistry of High Polymers 3 (3-0) s

Mechanisms and kinetics of polymerization; molecular weight description; theory of polymer solutions. Mr. Cates

Courses for Graduates Only

CH 623 Valence and the Structure of Organic Molecules 3 (3-0) f
Prerequisites: CH 223, CH 433

Applications of molecular orbital theory, thermodynamics, and free energy relations to organic problems. Mr. Jones

CH 625 Organic Reaction Mechanisms 3 (3-0) s
Prerequisites: CH 223, CH 433

A study of the effects of structure and substituents on the direction and rates of organic reactions. Mr. Bumgardner

CH 627 Chemistry of Metal-Organic Compounds 3 (3-0) f
Prerequisite: CH 521

Preparation, properties, and reactions of compounds containing the carbon-metal bond, with a brief description of their uses.
Messrs. Doak, Freedman

CH 631 Chemical Thermodynamics II 3 (3-0) s
Prerequisite: CH 531

Statistical interpretation of thermodynamics; use of partition functions; introduction to quantum statistics; application of statistical mechanics to chemical problems, including calculation of thermodynamic properties, equilibria, and rate processes. Messrs. Bowen, Sutton

CH 659 (BCH 659) Natural Products 3 (3-0) f
Prerequisite: CH 521

Synthetic and degradative procedures and conformational analysis in naturally occurring compounds, with emphasis on lipids, steroids, and carbohydrates. Mr. Levine

CH 691 Seminar 1 (1-0) fs
Prerequisite: Graduate standing in chemistry

Scientific articles, progress reports in research, and special problems of interest to chemists are reviewed and discussed. Graduate Staff

CH 693 Advanced Topics in Physical Chemistry 3 (3-0) fs
Prerequisites: Two of the following: CH 531, CH 533, CH 535, CH 537

An intensive treatment of selected topics of importance in current physicochemical research. Graduate Staff

CH 695 Special Topics in Chemistry Maximum 3 fs
Prerequisite: Permission of head of department

Critical study of special problems in one of the branches of chemistry.
Graduate Staff

CH 699 Chemical Research Credits by Arrangement fs
Prerequisite: Forty semester credits in chemistry

Special problems that will furnish material for a thesis. A maximum of six semester credits is allowed toward a master's degree; there is no limitation on credits in the doctorate program. Graduate Staff

DEPARTMENT OF CIVIL ENGINEERING

GRADUATE FACULTY

Professors: Donald Lee Dean, *Head,* Charles Raymond Bramer, Ralph Eigil Fadum, Carroll Lamb Mann, Jr., Charles Smallwood, Jr., *Graduate Administrator,* Mehmet Ensar Uyanik, Paul Zung-Teh Zia

Visiting Professor: Abdel-Aziz Ismail Kashef

Associate Professors: Michael Amein, Paul Day Cribbins, Charles Page Fisher, Clinton Louis Heimbach, John William Horn, Donald McDonald, Wesley Grigg Mullen, Harvey Edward Wahls

Assistant Professors: John Frederick Ely, William Sylvan Galler, Leonard Jay Langfelder

The Department of Civil Engineering offers programs of study leading to Master of Science and Doctor of Philosophy degrees. Graduate

course work is available in the fields of sanitary engineering, soil mechanics and foundation engineering, structural engineering, and transportation engineering. Whereas the Master of Science program would normally include course work in only one of these specialty fields, a program of study leading to the Doctor of Philosophy degree would encompass course work in a related combination of these fields.

Laboratory facilities for sanitary engineering research work include an hydraulics laboratory, a chemical laboratory, and a biological laboratory.

For work in soil mechanics and foundation engineering, a fully-equipped laboratory with modern soil-testing equipment is available.

Facilities for structural engineering research include a well-equipped physical testing laboratory, an air-controlled structural models laboratory, and a special laboratory for testing large models or full-scale structures.

Transportation engineering facilities are a bituminous laboratory, an airphoto interpretation laboratory, a photogrammetry laboratory, and a traffic engineering laboratory provided with traffic control devices.

In addition to these facilities, equipment for research is made available by the Department of Engineering Research.

Some unique opportunities for research are offered the graduate students in civil engineering by reason of the location of North Carolina State University in the state's capital city. There are a number of cooperative research endeavors with municipal and state governmental agencies that provide funds for research assistantships.

The resources of the institution also provide unique opportunities for combining studies in civil engineering with studies in other related fields.

The broad nature of water resources problems has been recognized by the creation of a "Water Resources Research Institute" under the joint direction of the Deans of the Graduate School, the School of Engineering and the School of Agriculture and Life Sciences. Students in the major disciplines are urged to select one of the many aspects of the control, conservation and management of this resource as a topic for study and research.

In recognition of the need by industry for personnel with training in water supply and the abatement of water pollution, the civil engineering department suggests that students in the many curricula leading to positions in industry (food processing, textile chemistry, pulp and paper technology, chemical engineering, zoology and others) consider courses of instruction in sanitary engineering for minor sequences for advanced degrees. Among the courses appropriate for such students are the following: CE 484, Water Resources Engineering II; CE 571, Theory of Water and Sewage Treatment; CE 573, Analysis of Water and Sewage; CE 673, Industrial Water Supply and Waste Disposal; and CE 674, Stream Sanitation.

There exists a growing need for the coordination of transportation facilities and land planning, and for individuals with competence in

both fields. To fulfill this need, an advanced program leading to a post-baccalaureate degree in engineering, majoring in transportation engineering, and to the degree of Master of Regional Engineering is offered through the combined resources of the Department of Civil Engineering at North Carolina State University and the Department of City and Regional Planning at the University of North Carolina at Chapel Hill. Qualified students have the opportunity to schedule their courses to enable them to qualify for both advanced degrees.

Information concerning the joint program may be obtained from the Department of Civil Engineering at North Carolina State in Raleigh or from the Department of City and Regional Planning at the University of North Carolina in Chapel Hill.

Courses for Advanced Undergraduates

CE 405, CE 406 TRANSPORTATION ENGINEERING I, II 4 (3-2) fs
Prerequisites: CE 201 for CE 405; CE 342 for CE 406
Required of seniors in civil engineering.

An integrated approach to the planning, design and operation of transportation systems. Engineering and economic aspects of the basic transport modes, including highway, rail, water and air facilities, are investigated from the viewpoint of the civil engineer.

CE 421 STRUCTURAL DESIGN I 3 (2-3) f
Prerequisites: CE 324, EM 301
Required of seniors in civil engineering and civil engineering construction option.

Basic design concepts. Analysis and design of tension, compression and flexural members in metal. Behavior and design of connections—riveted, bolted and welded. Term project in design of mill-building bent.

CE 422 STRUCTURAL DESIGN II 3 (2-3) s
Prerequisites: CE 332, CE 421, CE 425
Required of seniors in civil engineering.

Analysis and design, in reinforced concrete, of beams in flexure, diagonal tension, bond and anchorage; axially loaded columns, eccentrically loaded columns, footings, retaining walls, continuous beams and one-way slabs. Introduction to ultimate strength design. Term project in design of a multi-story building frame in reinforced concrete.

CE 425 STRUCTURAL ANALYSIS II 3 (2-3) f
Prerequisites: CE 324, EM 301
Required of seniors in civil engineering.

Deflection of beams and trusses; indeterminate stress analysis by moment area, slope deflection and moment distribution.

CE 429 STRUCTURAL DESIGN III 3 (2-3) s
Prerequisites: CE 332, CE 421
Required of seniors in civil engineering construction option.

Analysis and design of reinforced concrete beams, columns, footings and retaining walls. Design of timber beams, columns and connections. Term project in planning and making structural design for the timber forming needed for a reinforced concrete building.

CE 443 FOUNDATIONS 3 (3-0) s
Prerequisite: CE 421
Required of seniors in civil engineering construction option.

Identification and classification of soils; geological aspects of foundation engineering; methods of investigating subsoil conditions; control of water;

types of foundations and conditions favoring their use; legal concepts of foundation engineering.

CE 461 Project Planning and Control I 3 (2-3) f
Prerequisite: CE 362
Required of seniors in civil engineering construction option.

Analysis of construction plant layout requirements and performance characteristics of equipment.

CE 462 Project Planning and Control II 3 (2-3) s
Prerequisite: CE 461
Required of seniors in civil engineering construction option.

Scheduling, analysis and control of construction projects.

CE 464 Legal Aspects of Contracting 3 (3-0) s
Prerequisite: Senior standing
Required of seniors in civil engineering construction option.

Legal aspects of construction contract documents and specifications; owner-engineer-contractor relationships and responsibilities; bids and contract performance; labor laws.

CE 483 Water Resources Engineering I 3 (3-0) f
Prerequisite: CE 382
Required of seniors in civil engineering.

The hydrological cycle is studied with particular emphasis on those phases that are of engineering significance. The occurrence and distribution of water; rainfall, runoff, ground water. The development and control of water resources.

CE 484 Water Resources Engineering II 3 (3-0) s
Prerequisite: CE 483
Required of seniors in civil engineering.

A synthesis of mechanics, chemistry and hydrology in the design of elements of water resources systems. Water supply, treatment and distribution. Waste water collection, treatment and disposal. Consideration of flood control and stream flow regulation.

CE 485 Applied Hydraulics 3 (3-0) f
Prerequisite: EM 303
Required of seniors in civil engineering construction option.

Elements of fluid mechanics, hydraulics and hydrology, with application to problems in construction engineering.

Courses for Graduates and Advanced Undergraduates

CE 507 Airphoto Analysis I 3 (2-3) fs
Prerequisite: Junior standing

Engineering evaluation of aerial photographs, including analysis of soils and surface drainage characteristics. Mr. Wahls

CE 508 Airphoto Analysis II 3 (2-3) s
Prerequisite: CE 507

Engineering evaluation of aerial photographs for highway and airport projects. Mr. Wahls

CE 514 Municipal Engineering Projects 3 (2-3) s
Prerequisite: Senior standing

Special problems relating to public works, public utilities, urban planning and city engineering. Messrs. Horn, Smallwood

CE 515 Transportation Operations 3 (3-0) f
Prerequisite: CE 406

The analysis of traffic and transportation engineering operations.
Messrs. Heimbach, Horn

CE 516 Transportation Design 3 (2-3) s
Prerequisite: CE 406

The geometric elements of traffic and transportation engineering design.
Messrs. Cribbins, Horn

CE 517 Water Transportation 3 (3-0) f
Prerequisite: CE 405

The planning, design, construction and operation of waterways, ports, harbors and related facilities. Development of analytical techniques for evaluating the feasibility of piers, ports and multipurpose river basin projects. The design of marine structures and civil works that are significant in civil engineering, including locks, dams, harbors, ports and contractive and protective works. Mr. Cribbins

CE 524 Analysis and Design of Masonry Structures 3 (3-0) f
Corequisite: CE 425

Analysis and design of arches, culverts, dams, foundations and retaining walls. Mr. Bramer

CE 525, CE 526 Advanced Structural Analysis I, II 3 (3-0) fs
Prerequisite: CE 425

Analysis of rigid frames and continuous structures; treatment of redundant members and secondary stresses. Messrs. Dean, Ely

CE 527 Numerical Methods in Structural Analysis 3 (3-0) s
Prerequisite: CE 425

Newmark's numerical integration procedure and its applications; matrix operations, relaxation and iteration, finite difference method. Force and displacement methods, string polygon method. High-speed computation.
Mr. McDonald

CE 531 Experimental Stress Analysis 3 (2-3) f
Prerequisite: CE 425

Principles and methods of experimental analysis; dimensional analysis; applications to full-scale structures. Mr. Bramer

CE 534 Plastic Analysis and Design 3 (3-0) s
Prerequisite: CE 421

Analysis of steel structure behavior beyond the elastic limit; concept of design for ultimate load and the use of load factors. Analysis and design of component parts of frames. Methods of predicting strength and deformation behavior of structures loaded in the plastic range. Bracing and connecting requirements for frame. Mr. Bramer

CE 535 Ultimate Strength Theory and Design 3 (3-0) f
Prerequisite: CE 422

Ultimate strength theories of axially loaded column, flexure, combined flexure and axial load, shear. Critical review of important research and their relationship with the development of modern design codes for reinforced concrete. Mr. Zia

CE 536 Theory and Design of Prestressed Concrete 3 (3-0) s
Prerequisite: CE 422

The principles of prestressed concrete. Materials. Methods of prestressing. Loss of prestress. Design of beams for bending, shear and bond. Ultimate strength. Deflection. Composite beams. Continuous beams. Special topics. Design projects. Mr. Zia

CE 544 Foundation Engineering 3 (3-0) fs
Prerequisite: CE 342

Subsoil investigations; excavations; design of sheeting and bracing sys-

tems; control of water; footing, grillage and pile foundations; caisson and cofferdam methods of construction; legal aspects of foundation engineering.
Messrs. Kashef, Langfelder

CE 547 Fundamentals of Soil Mechanics 3 (3-0) fs
Prerequisite: EM 301

Physical and mechanical properties of soils governing their use for engineering purposes; stress relations and applications to a variety of fundamental problems. Mr. Wahls

CE 548 Engineering Properties of Soils I 3 (2-3) f
Prerequisite: CE 342

The study of soil properties that are significant in earthwork engineering, including properties of soil solids, basic clay mineral concepts, classification, identification, plasticity, permeability, capillarity and stabilization. Laboratory work includes classification, permeability and compaction tests. Messrs. Kashef, Langfelder

CE 549 Engineering Properties of Soils II 3 (2-3) s
Prerequisite: CE 548

Continuation of CE 548, including the study of compressibility, stress-strain relations and shear strength theories for soil. Laboratory work includes consolidation and shear strength tests. Mr. Langfelder

CH 570 See MB 570, Sanitary Microbiology. 3 (2-3) fs

CE 571 Theory of Water and Sewage Treatment 3 (3-0) f
Prerequisite: Graduate standing

Study of the physical and chemical principles underlying water and sewage treatment processes; diffusion of gases, solubility, equilibrium and ionization, anaerobic and aerobic stabilization processes, sludge conditioning and disposal. Mr. Galler

CE 572 Unit Operations and Processes in Sanitary Engineering 3 (1-6) s
Prerequisite: CE 571

Processes and operations in sanitary engineering; sedimentation, aeration, filtration, adsorption, coagulation, softening, sludge digestion, aerobic treatment of sewage. Mr. Smallwood

CE 573 Analysis of Water and Sewage 3 (1-6) f
Corequisite: CE 571

Chemical and physical analysis of water and sewage and interpretation of results. Messrs. Galler, Smallwood

CE 574 Radioactive Waste Disposal 3 (2-3) fs
Prerequisite: PY 407

Unit operations and processes employed in treatment and disposal of radioactive wastes. Mr. Smallwood

CE 580 Flow in Open Channels 3 (3-0) fs
Prerequisite: CE 483

The theory and applications of flow in open channels, including dimensional analysis, momentum-energy principle, gradually varied flow, high-velocity flow, energy dissipators, spillways, waves, channel transitions and model studies. Mr. Amein

CE 591, 592 Civil Engineering Seminar 1 (1-0) fs

Discussions and reports of subjects in civil engineering and allied fields.
Graduate Staff

CE 598 Civil Engineering Projects 1 to 6 arranged fs

Special projects in some phase of civil engineering. Graduate Staff

Courses for Graduates Only

CE 601 Transportation Planning 3 (3-0) s
Prerequisite: CE 515

The planning, administration, economics and financing of various transportation engineering facilities. Mr. Cribbins

CE 602 Advanced Transportation Design 3 (2-3) f
Prerequisite: CE 516

Design of major traffic and transportation engineering projects. Mr. Heimbach

CE 603 Airport Planning and Design 3 (2-3) f
Corequisite: CE 515

The analysis, planning and design of air transportation facilities. Messrs. Heimbach, Horn

CE 604 Urban Transportation Planning 3 (3-0) s
Prerequisite: CE 515

Thoroughfare planning as related to land usage and urban master-planning. Messrs. Heimbach, Horn

CE 623 Theory and Design of Arches 3 (3-0) f
Prerequisites: CE 422, CE 526

General theory of elastic arches. Boundary conditions and their effect on behavior of the arch. Single span, multiple span arches on elastic piers, influence lines of various functions under moving loads, economical layout of arches, design criteria for steel and concrete arches. Mr. Uyanik

CE 624 Analysis and Design of Structural Shells and Folded Plates 3 (3-0) s
Prerequisites: CE 623, EM 511

Roof structures consisting of surfaces of revolution, both single and compound curved. Membrane stresses, bending stresses at boundaries. Domes and cylindrical shells. Approximate and exact analyses. Design criteria. Folded plane structures of concrete plates and steel frames. Messrs. Dean, Uyanik

CE 625, 626 Advanced Structural Design I, II 3 (2-3) fs
Prerequisite: CE 422
Corequisites: CE 525, CE 526

Complete structural designs of a variety of projects; principles of limit and prestress design. Mr. Uyanik

CE 627 Design of Blast Resistant Structures 3 (3-0) f
Prerequisites: CE 526, EM 555

Sources, intensities, and methods of transmission of dynamic loads. Behavior of structures and structural elements subjected to dynamic forces. Design criteria and factor of safety. Design of surface and underground structures for nuclear blasts. Mr. McDonald

CE 641, 642 Advanced Soil Mechanics 3 (3-0) fs
Prerequisite: Graduate standing

Theories of soil mechanics; failure conditions; mechanical interaction between solids and water, and problems in elasticity pertaining to earthwork engineering soil dynamics. Mr. Wahls

CE 643 Hydraulics of Ground Water 3 (3-0) fs
Prerequisite: Graduate standing

Principles of ground water hydraulics; theory of flow through idealized porous media; the flow net solution; seepage and well problems. Mr. Kashef

CE 671 Advanced Water Supply and Sewerage 4 (3-3) f
Prerequisite: CE 484

Problems relating to the design of water supply and sewerage works.
Mr. Smallwood

CE 672 Advanced Water and Sewage Treatment 4 (3-3) s
Prerequisite: CE 484

Problems relating to the treatment of water and sewage.
Mr. Smallwood

CE 673 Industrial Water Supply and Waste Disposal 3 (3-0) fs
Corequisite: CE 571

Water requirements of industry and the disposal of industrial wastes.
Mr. Galler

CE 674 Stream Sanitation 3 (3-0) fs
Corequisite: CE 571

Biological, chemical and hydrological factors that affect stream sanitation and stream use. Messrs. Galler, Smallwood

CE 698 Special Topics in Civil Engineering 1 to 3 arranged fs

The study of special advanced topics of particular interest in various areas of civil engineering. Graduate Staff

CE 699 Civil Engineering Research Credits by Arrangement fs

Independent investigation of an advanced civil engineering problem; a report of such an investigation is required as a graduate thesis.
Graduate Staff

DEPARTMENT OF CROP SCIENCE

GRADUATE FACULTY

Professors: Paul H. Harvey, *Head,* Charles A. Brim, Douglas Scales Chamblee, James Ferris Chaplin, Dan Ulrich Gerstel, Walton Carlyle Gregory, Guy Langston Jones, Kenneth Raymond Keller, Glenn Charles Klingman, Roy Lee Lovvorn, Thurston Jefferson Mann, Philip Arthur Miller, Robert Parker Moore, Donald Edwin Moreland, Lyle L. Phillips, Donald Loraine Thompson, Joseph Arthur Weybrew

Professor Emeritus: Gordon Kennedy Middleton

Associate Professors: Carl Thomas Blake, Will Allen Cope, Donald Allen Emery, William Best Gilbert, Harry Douglas Gross, Joshua Alexander Lee, William Mason Lewis, Jackson R. Mauney, David Harry Timothy, Arch Douglas Worsham

Assistant Professors: Thaddeus Hillery Busbice, William Thomas Fike, George Richard Gwynn, Darrell Alvin Miller, Charles Franklin Murphy, Howard Gordon Small, Jerome Bernard Weber, Earl Allen Wernsman

The Department of Crop Science offers instruction leading to the Master of Science and Doctor of Philosophy degrees in the fields of plant breeding, crop production, forage crops ecology, weed control, and plant chemistry. For students who wish general training, the Master of Agriculture degree is offered.

Excellent facilities for graduate training are available. Each student is assigned office and laboratory space. Many special facilities such as preparation rooms for plant and soil samples, cold storage facilities for plant material, air-conditioned rooms for studying the physical properties of cotton fiber and tobacco leaf, and soil and plant

analytical service laboratories are available. Greenhouse space and growth control chambers are provided for projects which require these facilities. Sixteen farms are owned and operated by the state for research investigations. These farms are located throughout North Carolina, and include a wide variety of soil and climatic conditions needed for experiments in plant breeding, crop management, forage ecology, and weed control.

Strong supporting departments greatly increase opportunities for broad and thorough training. Included among those departments in which graduate students in crop science work cooperatively or obtain instruction are botany, chemistry, genetics, horticultural science, mathematics, plant pathology, entomology, soil science, and statistics.

In North Carolina, a state which derives 80 percent of its agricultural income from farm crops, the opportunities for the well-trained agronomist are exceedingly great. Recipients of advanced degrees in crop science at North Carolina State are found in positions of leadership in research and education throughout the nation and the world.

Courses for Advanced Undergraduates

CS 413 PLANT BREEDING 3 (3-0) s
Prerequisite: GN 411

The application of genetic principles to the improvement of economic plants, including discussions of the methods employed in the development and the perpetuation of desirable clones, varieties, and hybrids.
Mr. Emery

CS 414 WEEDS AND THEIR CONTROL 3 (2-2) f
Prerequisite: CH 220 or equivalent

Principles involved in cultural and chemical weed control. Discussions on chemistry of herbicides and the effects of the chemicals on the plant. Identification of common weeds and their seeds is given. Mr. Klingman

Courses for Graduates and Advanced Undergraduates

CS 511 TOBACCO TECHNOLOGY 2 (2-0) s
Prerequisites: CS 311, BO 421 or equivalent

A study of special problems concerned with the tobacco crop. The latest research problems and findings dealing with this important cash crop will be discussed. Staff

CS 512 GRASSLAND DYNAMICS 2 (2-0) s
Prerequisites: BO 421, ZO 421 or equivalent

A discussion of forage production practices of national and international importance. An attempt will be made to relate the seemingly divergent practices to fundamentals of physiology and ecology. The dynamic relationship among soil, plant, animal and man, as it affects production practices and research, will be emphasized. (Offered in 1966-67 and alternate years.)
Mr. Gross

CS 541 (GN 541, HS 541) PLANT BREEDING METHODS 3 (3-0) f
Prerequisites: GN 512, ST 511 recommended

An advanced study of methods of plant breeding as related to principles and concepts of inheritance. Messrs. Haynes, Timothy

CS 542 (GN 542, HS 542) PLANT BREEDING FIELD PROCEDURES 2 (0-4) summer
Prerequisite: CS 541 or GN 541 or HS 541

Laboratory and field study of the application of the various plant breeding techniques and methods used in the improvement of economic plants.
Mr. Harvey

CS 591 SPECIAL PROBLEMS Credits by Arrangement
Prerequisite: Permission of instructor

Special problems in various phases of crop science. Problems may be selected or will be assigned. Emphasis will be placed on review of recent and current research. Graduate Staff

Courses for Graduates Only *

CS 611 FORAGE CROP ECOLOGY 2 (2-0) s
Prerequisite: BO 442

A study of the effect of environmental factors on the growth of forage crops. Attention will be given to methods of research in forage ecology.
Mr. Chamblee

CS 612 SPECIAL TOPICS IN WEED CONTROL 2 (2-0) s
Prerequisites or Corequisites: CS 414, CH 223, BO 588

Detailed examination of current concepts and literature of weed control. The chemistry, physiology, ecology, taxonomy, microbiology, equipment, and techniques used in weed control research will be discussed.
Graduate Staff

CS 613 (GN 613, HS 613) PLANT BREEDING THEORY 3 (3-0) s
Prerequisites: CS 541 or equivalent, GN 513, ST 512 (A course in quantitative genetics is recommended.)

A study of theoretical bases for plant breeding procedures with special emphasis on the relationship between type and source of genetic variability, mode of reproduction and effectiveness of different selection procedures. The latest experimental approaches to plant breeding will be discussed as well as standard procedures. Mr. Miller

CS 690 SEMINAR 1 (1-0) fs
Prerequisite: Graduate standing
A maximum of two credits is allowed toward the master's degree, however, additional credits toward the doctorate are allowed.

Scientific articles, progress reports in research, and special problems of interest to agronomists reviewed and discussed. Graduate Staff

CS 699 RESEARCH Credits by Arrangement
Prerequisite: Graduate standing
A maximum of two credits is allowed towards the master's degree, but no restrictions toward the doctorate. Graduate Staff

DEPARTMENT OF ECONOMICS

GRADUATE FACULTY

Professors: CHARLES EDWIN BISHOP, *Head,* GEORGE LAFAYETTE CAPEL, ARTHUR JAMES COUTU, HERMAN BROOKS JAMES, RICHARD ADAMS KING, JAMES GRAY MADDOX, BERNARD MARTIN OLSEN, WALTER HENRY PIERCE, ERNST WARNER SWANSON, GEORGE STANFORD TOLLEY, WILLIAM DOUGLAS TOUSSAINT, *Coordinator of Graduate Programs,* JAMES CLAUDE WILLIAMSON, JR.

* Students are expected to consult the instructor before registration.

Associate Professors: Louis Arnold Dow, Leigh Hugh Hammond, Cleon Wallace Harrell, William Ray Henry, Dale Max Hoover, Loren Albert Ihnen, Paul Reynolds Johnson, Edgar Walton Jones, Charles Ray Pugh, James Arthur Seagraves, Richard Lee Simmons, Thomas Dudley Wallace

Assistant Professors: Joe Senter Chappell, Magdi Mohamed El-Kammash, Ernest Caleb Pasour, Jr., Ralph James Peeler, Jr., George Anthony Spiva, Jr., Carl Byron Turner, Donald Albert West

Visiting Assistant Professor: Gene Arthur Mathia

U.S.D.A. Agricultural Economist: Joseph Gwyn Sutherland

The Department of Economics offers programs of study leading to the Master of Economics, the Master of Science in Agricultural Economics and the Doctor of Philosophy degrees. The curriculum includes courses in economic theory, history of economic thought and fields of specialization, including econometrics, marketing, agricultural economics, international trade, economic development and business management analysis. Special attention is given in the curriculum to the development of quantitative analysis skills in economics and to an understanding of economic factors and public policies as they affect regional, national and international development.

Collateral fields of study include statistics, history, politics, sociology, psychology, education and other related fields.

The increasing emphasis being placed on economic growth and development in the South, the nation and throughout the world has resulted in an increased demand for well-trained workers in economics. Graduates of the department with a Master of Economics or a Master of Science degree have opportunities to work in industry, for federal and state agencies and to teach, particularly in the rapidly-expanding community college or junior college systems.

Doctor of Philosophy graduates have opportunities for employment as teachers and research workers in universities throughout the nation. Many also find excellent opportunities in various agencies of federal and state government where they are involved in research and educational work. International development agencies employ some graduates, and others find employment as research workers with commercial firms.

The department is located on the first floor of Harrelson Hall and the second floor of Patterson Hall. Graduate students on assistantships or fellowships are provided with office space and equipment, and other graduate students are provided office space when it is available. The department has a modern and well-equipped departmental library, including all the major professional journals. Research reports from federal and state governmental agencies and from universities throughout the United States also are kept on file.

Computational facilities are ideal for students whose research problems involve extensive analysis of data, as well as for those students who want to learn to do their own programming. The department has a well-trained clerical staff and has one-half interest

in an IBM 1620 computer which is available to students. Early in 1966, the full computer resources of the new tri-university center at the Research Triangle will be available. The basic facility will be an IBM 360, Model 75 system, with extended facilities on each campus including North Carolina State University.

Courses for Advanced Undergraduates

EC 403 Family Economics 3 (3-0) s
Prerequisite: Permission of instructor

This course is concerned with the study of economic principles relevant to the use of family resources in achieving family goals. Primary emphasis is placed on decision making as the central problem of family economics. Special attention is given to the resources controlled by the family and the factors affecting the use of these resources. Specific applications of these principles to problems in family management will be studied. Staff

EC 407 Business Law I 3 (3-0) fs
Prerequisite: Basic courses in economics

A course dealing with elementary legal concepts, contracts, agency, negotiable instruments, sales of personal property, chattel mortgages, partnerships, corporations, suretyship and bailments, insurance.
Mr. Dixon, Miss Hunt

EC 408 Business Law II 3 (3-0) fs
Prerequisite: EC 407

Deals with real property, mortgages on urban and farm lands, landlord and tenant, requirements for valid deed, insurance law, wills, suretyship and conditional sales. Mr. Dixon

EC 409 Introduction to Production Cost 3 (3-0) fs
Prerequisite: EC 312

An introduction to accounting problems peculiar to manufacturing, fabrication, and construction-type enterprises. Cost determination and allocation of costs for materials, labor, and overhead to the various units of product. Estimating and cost control in the production and manufacturing process. Special emphasis to be placed on managerial analysis and interpretation of cost data. Staff

EC 410 Industry Studies 3 (3-0) f
Prerequisite: EC 201 or EC 205

An analysis of organization, market structure, and competitive behavior in specific industries using the tools of the economist as a guide to pertinent factors and their significance. The course will be organized along the lines of intensive but broadly-relevant case-studies. Staff

EC 411 Marketing Methods 3 (3-0) fs
Prerequisite: Basic courses in economics

Marketing institutions and their functions and agencies; retailing; market analysis; problems in marketing. Staff

EC 413 Competition, Monopoly, and Public Policy 3 (3-0) fs
Prerequisites: EC 201 or EC 205, EC 301

An analysis of the effect of modern industrial structure on competitive behavior and performance, in the light of contemporary price theory and the theory of workable competition. A critical evaluation of the legislative content, judicial interpretation, and economic effects of the antitrust laws.
Mr. Erickson

EC 414 Tax Accounting 3 (2-2) fs
Prerequisite: EC 312

An analysis of the federal tax laws relating to the individual and busi-

ness. Determining and reporting income. Payroll taxes and methods of reporting them. Actual practice in the preparation of income tax returns.
Mr. Fails

EC 415 Farm Appraisal and Finance 3 (2-3) s
Prerequisite: EC 303

Examination of the source of the productivity and value of farm inputs; a critical analysis of, and practice in the use of, farm appraisal procedures currently used for land and buildings; review of the sources of, and repayment practices used in short and intermediate credit in agriculture; consideration of the forces operating in the whole economy with an examination of the implications of these changes for both the lender and borrower in agriculture. Mr. Neuman

EC 417 Introduction to Economic Dynamics 3 (3-0) fs
Prerequisites: EC 301, EC 302

The course has a twofold purpose: 1) to acquaint the student with the procedures and problems involved in the formulation and application of theories and models in economics, and 2) to investigate some existing theories and models, drawn from various parts of economics, which possess dynamic properties. Mr. El-Kammash

EC 420 Corporation Finance 3 (3-0) fs
Prerequisite: EC 201 or EC 205

Financial instruments and capital structure; procuring funds; managing working capital; managing corporate capitalization; financial institutions and their work. Mr. Ufen

EC 425 Industrial Management 3 (3-0) fs
Prerequisite: Junior standing

Principles and techniques of modern scientific management; relation of finance, marketing, industrial relations, accounting, and statistics to production; production planning and control; analysis of economic, political and social influences on production. Mr. Wood

EC 426 Personnel Management 3 (3-0) fs
Prerequisite: Junior standing

The scientific management of manpower, from the viewpoint of the supervisor and the personnel specialist. A study of personnel policy and a review of the scientific techniques regarding the specific problems of employment, training, promotion, transfer, health and safety, employee services, and joint relations. Mr. Wood

EC 430 Agricultural Price Analysis 3 (3-0) f
Prerequisite: EC 212

Principles of price formation; the role of prices in the determination of economic activity; the interaction of cash and future prices for agricultural commodities; methods of price analysis, construction of index numbers, analysis of time series data including the estimation of trend and seasonal variations in prices. Mr. Schrimper

EC 431 Labor Problems 3 (3-0) fs
Prerequisite: Junior standing

An economic approach to labor problems including wages, hours, working conditions, insecurity, substandard workers, minority groups, social security, and public policy relative to these problems. Mr. Fearn

EC 432 Industrial Relations 3 (3-0) fs
Prerequisite: Junior standing

Collective bargaining. Analysis of basic labor law and its interpretation by the courts and governmental agencies. An examination of specific terms of labor contracts and their implications for labor and management. An

examination of labor objectives and tactics and management objectives and tactics. Problems of operating under the labor contract. Mr. Bartley

EC 440 Economics of Growth 3 (3-0) s
Prerequisite: EC 201 or EC 205

An examination of the institutional background required for national economic development. The conditions apparent for past growth of nations are compared with conditions obtained in presently retarded nations. Conclusions are drawn from this comparison to provide an introduction to theoretical models of growth. Mr. Olsen

EC 441 Agricultural Development in Foreign Countries 3 (3-0) s
Prerequisite: EC 212, EC 202 or EC 205

Identification of agricultural problems in underdeveloped countries; a review of economic criteria for analyzing the problems of developing agriculture and the techniques of analysis for solving such problems. Case studies of development programs in various countries will be discussed. Staff

EC 442 Evolution of Economic Ideas 3 (3-0) fs
Prerequisite: Basic courses in economics

An analysis of the development of economic thought and method during the past two centuries. Economics considered as a cumulative body of knowledge, in a context of emerging technology, changing institutions, pressing new problems, and the growth of science. Mr. Turner

EC 446 Economic Forecasting 3 (3-0) f
Prerequisite: EC 201 or EC 205, EC 302 recommended but not required

An examination of the basic principles and techniques of economic forecasting with strong emphasis upon the economic models upon which forecasting is based. Mr. El-Kammash

EC 448 International Economics 3 (3-0) f
Prerequisite: EC 201 or EC 205

A study of international economics, including trade, investment, monetary relations, and certain aspects of economic development. Emphasis upon analytical and policy approaches, although some institutional material is included. Staff

EC 450 Economic Decision Processes 3 (3-0) s
Prerequisites: EC 201 or EC 205, MA 202 or MA 212

An analysis of processes for decision making by individuals and groups. Linear programming, probability, and game theory in the light of a general theory of decision. Mr. Harrell

EC 490, 491 Senior Seminars in Economics 3 (3-0) fs
Prerequisite: Permission of instructors

The terminal courses in undergraduate study of economics. The student is assisted in summarizing his training, and in improving his capacity to recognize problems and to select logically consistent means of solving the problems. This is done on a small-group and individual basis. Staff

EC 492 Seminar in Contemporary Economic Problems in Agriculture 1 (0-2) s
Prerequisite: Permission of instructor

Analysis of economic problems of current interest in agriculture. Credit for this course will involve a scientific appraisal of a selected problem and alternative solutions. Mr. Bishop

Courses for Graduates and Advanced Undergraduates

EC 501 Intermediate Economic Theory 3 (3-0) fs
Prerequisite: EC 301, EC 212 or equivalent

An intensive analysis of the determination of prices and of market behavior, including demand, cost and production, pricing under competitive conditions, and pricing under monopoly and other imperfectly competitive conditions. Mr. Dow

EC 502 Money, Income, and Employment 3 (3-0) fs
Prerequisite: EC 302 or EC 501, or equivalent

A study of the methods and concepts of national income analysis with particular reference to the role of monetary policy in maintaining full employment without inflation. Mr. Wilson

EC 510 (PS 510) Public Finance 3 (3-0) f
Prerequisite: EC 201 or EC 205

A survey of the theories and practices of governmental taxing, spending, and borrowing, including intergovernmental relationships and administrative practices and problems. Mr. Wilson

EC 512 Economic Analysis of Agricultural Factor Markets 3 (3-0) s
Prerequisite: EC 212 or equivalent

An examination of the roles of land, labor and capital as factors of production in a modern agricultural economy, including major changes in the roles of these factors in recent years; analysis of changes in the supply and demand for the factors; a review of the structure and efficiency of markets for the factors, including relevance of the institutional and attitudinal setting in each type of market and an investigation of the nature of the demand-supply equilibration; a consideration of public policies relating to the use of the factors of production in agriculture in relation to theories of economic growth, with particular attention to land, credit, education and research programs affecting the factors of production used in agriculture in developing economies. Mr. Tolley

EC 521 Procurement, Processing and Distribution of Agricultural Products 3 (3-0) f
Prerequisite: EC 311 or equivalent

A study of marketing firms as producers of marketing services and their role in the pricing process; the influence of government policies on their behavior of marketing firms; methods for increasing the efficiency of marketing agricultural products. Mr. King

EC 523 Planning Farm and Area Adjustments 3 (3-0) s
Prerequisite: EC 303 or equivalent

The application of economic principles in the solution of production problems on typical farms in the state; methods and techniques of economic analysis of the farm business; application of research findings to production decisions; development of area agricultural programs. Mr. Coutu

EC 525 Management Policy and Decision Making 3 (3-0) f
Prerequisites: Nine hours in economics and related courses and permission of instructor

A review and consideration of modern management processes used in making top-level policies and decisions. An evaluation of economic, social and institutional pressures, and of the economic and non-economic motivations, which impinge upon the individual and the organization. The problem of coordinating the objectives and the mechanics of management is examined. Mr. Erickson

EC 531 Management of Industrial Relations 3 (3-0) s
Prerequisites: Nine hours in economics and related courses, permission of instructor

A seminar course designed to round out the technical student's program. Includes a survey of the labor movement organization and structure of unions, labor law and public policy, the union contract, the bargaining pro-

cess, and current trends and tendencies in the field of collective bargaining.
Graduate Staff

EC 533 AGRICULTURAL POLICY 3 (3-0) s
Prerequisite: EC 212 or equivalent

A review of the agricultural policy and action programs of the federal government in their economic and political setting; analysis of objectives, principal means, and observable results under short-term and long-term viewpoints, and under the criteria of resource use and income distribution within agriculture, and between agriculture and the rest of the economy; appraisal of alternative policy proposals; the effects of commodity support programs of domestic and foreign consumption, and some of the international aspects of United States agricultural policy; the attempts at world market regulation, and the role of international organizations, agreements, and programs. Mr. Hoover

EC 541 ORIGINS OF THE UNITED STATES' ECONOMY 3 (3-0) f
Prerequisites: Senior or graduate standing, EC 302, HI 261 or HI 333, or equivalent

A seminar on growth and development of American economic institutions. Emphasis is placed on the relationship between the growth of the economy of the United States and theories of economic development.
Mr. Olsen

EC 550 MATHEMATICAL MODELS IN ECONOMICS 3 (3-0) fs
Prerequisites: EC 201 or EC 205, MA 202 or MA 212, EC 450 recommended but not required

An introductory study of economic models emphasizing their formal properties. The theory of individual economic units is presented as a special case in the theory of inductive behavior. Mathematical discussions of the theory of the consumer, the theory of the firm, and welfare economics will show the relevance of such topics as constrained maxima and minima, set theory, partially and simply ordered systems, probability theory, and game theory to economics. Mr. Harrell

EC 551 AGRICULTURAL PRODUCTION ECONOMICS 3 (3-0) f
Prerequisite: EC 212 or equivalent

An economic analysis of agricultural production, including production functions, cost functions, programming and decision-making principles; and the applications of these principles to farm and regional resource allocation, and to the distribution of income to and within agriculture.
Mr. Toussaint

EC 552 ECONOMETRICS 3 (3-0) fs
Prerequisites: EC 201 or EC 205, MA 202 or MA 212, ST 361

An analysis of methods for economic inference. Multi-equation economic models; their specification, identification, and estimation.
Messrs. El-Kammash, Schrimper

EC 555 LINEAR PROGRAMMING 3 (3-0) fs
Prerequisites: EC 201 or EC 205, MA 202 or MA 212, MA 405

Recent developments in the theory of production, allocation, and organization. Optimal combination of integrated productive processes within the firm. Applications in the economics of industry and of agriculture.
Mr. Harrell

EC 561 CONSUMPTION, DISTRIBUTION, AND PRICES IN AGRICULTURE 3 (3-0) s
Prerequisite: EC 212 or equivalent

Basis for family decisions concerning consumption of goods and services and supply of productive factors; forces determining prices and incomes; interrelationships between economic decisions of the household and the firm. Mr. West

EC 590, 591 Seminar in Special Economic Topics 3 (3-0) fs
Prerequisite: Permission of instructor

Topics presented by a visiting professor or special lecturer. This course will be offered from time to time as distinguished visiting scholars are available. Graduate Staff

EC 592 Topical Problems in Agricultural Economics Maximum 6 fs
Prerequisite: Permission of instructor

An examination of current problems in the field of agricultural economics with emphasis on the use of theory to define and facilitate the consideration of alternative solutions. Graduate Staff

Courses for Graduates Only

EC 601 Advanced Economic Theory 3 (3-0) fs
Prerequisite: EC 501 or equivalent

A rigorous examination of contemporary microeconomic theory.
Graduate Staff

EC 602 Monetary and Employment Theory 3 (3-0) s
Prerequisite: EC 502 or equivalent

The course consists of an analysis of the forces determining the level of income and employment; a review of some of the theories of economic fluctuations; and a critical examination of a selected macroeconomic system.
Mr. Tolley

EC 603 History of Economic Thought 3 (3-0) f
Prerequisite: EC 442 or EC 501, or equivalent

A systematic analysis of the development and cumulation of economic thought, designed in part to provide a sharper focus and more adequate perspective for the understanding of contemporary economics.
Mr. Turner

EC 611 Agricultural Economic Analysis 3 (3-0) f
Prerequisites: MA 112, EC 551 or equivalent

An economic analysis of agricultural products and inputs. Includes analysis of price-determining forces and factors influencing distribution of income within agriculture and between agriculture and the rest of the economy. Production, cost and demand functions are stressed, along with programming and decision-making principles and their application to decisions at the firm level and to regional resource allocation. Mr. Ihnen

EC 612 International Trade in Relation to Agriculture 3 (3-0) f
Prerequisites or Corequisites: EC 602, EC 611

The principles of international and interregional trade; structures of trade relationships between countries engaged in the import or export of agricultural products; attempts at stabilizing trade and financial transactions. Mr. Johnson

EC 631 Economic and Social Foundations of Agricultural Policy 3 (3-0) f
Prerequisite: EC 501 or equivalent

The study of logical and empirical problems of inquiry into public policies and programs that affect agriculture; analysis of policy-making processes, interdependencies among economic, political and social objectives and action; the study of forces which shape economic institutions and goals and of the logic, beliefs and values on which policies and programs that affect agriculture are founded. Graduate Staff

EC 632 Welfare Effects of Agricultural Policies and Programs 3 (3-0) s
Prerequisite: EC 611

Description of the conditions defining optimal resource allocation; application of the conditions for maximum welfare in appraisal of economic policies and programs affecting resource allocation, income distribution, and economic development of agriculture. Mr. Bishop

EC 640 Theory of Economic Growth 3 (3-0) fs
Prerequisite: EC 440 or EC 502, or equivalent

Several theoretical models of economic growth are compared and analyzed. Contemporary developments in the theory of national economic growth are studied and evaluated for consistency with older theories.
Mr. Olsen

EC 641 Economics of Production, Supply and Market Interdependency 3 (3-0) s
Prerequisites or Corequisites: EC 611, MA 211 or equivalent

An advanced study in the logic of, and empirical inquiry into, producer behavior and choice among combinations of factors and kinds and quantities of output; aggregative consequences of individuals' and firms' decisions in terms of product supply and factor demand; factor markets and income distribution; general interdependency among economic variables.
Graduate Staff

EC 642 Economics of Consumption, Demand and Market Interdependency 3 (3-0) f
Prerequisites: EC 611, ST 513 or equivalent

An advanced study in the theory of, and research related to, household behavior; aggregative consequences of household decisions concerning factor supply and product demand; pricing and income distribution; economic equilibrium. Mr. King

EC 648 Theory of International Trade 3 (3-0) s
Prerequisite: EC 448 or EC 501, or equivalent

A consideration, on a seminar basis, of the specialized body of economic theory dealing with the international movement of goods, services, capital, and payments. Also, a theoretically-oriented consideration of policy.
Mr. Swanson

EC 650 Economic Decision Theory 3 (3-0) fs
Prerequisites: EC 501 or equivalent, EC 550 or EC 555

Study of general theories of choice. Structure of decision problems; the role of information; formulation of objectives. Current research problems.
Mr. Harrell

EC 651 (ST 651) Econometric Methods I 3 (3-0) f
Prerequisites: ST 422, ST 502, EC 611 or equivalent

The role and uses of statistical inference in economic research; measurement problems and their solutions arising from the statistical model and the nature of the data; limitations and interpretation of results of economic measurement from statistical techniques. Topics include the problems of specification, aggregation, identification, multicolinearity and autocorrelation. Attention also is given to expectations models and simultaneous stochastic equations.
Mr. Wallace

EC 652 (ST 652) Econometric Methods II 3 (3-0) s
Prerequisite: EC-ST 651

Survey of current literature on estimation and inference in simultaneous stochastic equations systems. Techniques for combining cross section and time series data including covariance, error correlated and error component models. Lag models and inference in dynamic systems. Production functions, productivity measurement and hypotheses about economic growth. Complete and incomplete prior information in regression analysis. Nonlinear estimation in economic models. (Offered 1965-66 and alternate years.)
Graduate Staff

EC 655 Topics in Mathematical Economics 3 (3-0) fs
Prerequisites: EC 501 or equivalent, EC 550 or EC 555

A seminar and research course devoted to recent literature and developments in mathematical economics. Mr. Harrell

EC 665 Economic Behavior of the Organization 3 (3-0) s
Prerequisites: EC 501 or equivalent, permission of instructor

This seminar will apply methods and findings derived from the behavioral sciences to the economic behavior of the organization, particularly the business firm. Among the approaches which may be utilized are organization theory, information theory, reference group theory, and decision theory. Mr. Swanson

EC 671 Analysis of Economic Development in Agriculture 3 (3-0) s
Prerequisite: EC 641

A theoretical and empirical study of the processes of economic growth; the problems of underdeveloped countries; the role of agriculture in a developing economy; an examination of policies and programs needed for effective economic development. Mr. Maddox

EC 699 Research in Economics Credits by Arrangement
Prerequisite: Graduate standing

Individual research in economics, under staff supervision and direction. Graduate Staff

SCHOOL OF EDUCATION

GRADUATE FACULTY

Dean: James Bryant Kirkland

Associate Professors: Harry G. Beard, Norman M. Chansky

The School of Education offers graduate programs leading to the master's degree for students majoring in Agricultural Education, Industrial Arts Education, Vocational, Industrial and Technical Education, Mathematics Education, Occupational Information and Guidance, Industrial Psychology, Adult Education, and Science Education. Graduate students in education may pursue programs leading to the degree of Master of Science or Master of Education.

The Master of Science degree is regarded as a research degree and as preparation for further graduate study. Programs leading to the Master of Science degree are planned to include a major (twenty credit hours) in some specialized area of education and a minor (ten or more credit hours) in some other field such as psychology or agricultural economics. If two minors are chosen, a minimum of six credits will be required in each.

A reading knowledge of one modern foreign language is required and a thesis representing an original investigation in the major field must be prepared.

The Master of Education degree is designed to meet the needs of students preparing to teach in secondary schools and community colleges and to assume leadership positions in adult education programs. The program of study for the professional degree allows a wider latitude in the choice of course work outside the major than is allowed by the Master of Science program.

A problem may be substituted for a thesis if, in the opinion of the student's advisory committee, this alternative contributes maximally to the student's objective. Knowledge of a foreign language is not required for the Master of Education degree.

The School of Education is located in Tompkins Hall where laboratories and research facilities are provided for graduate study.

A limited number of teaching and research assistantships are available for qualified graduate students. National Defense Education Act loans are also available for graduate students needing financial aid.

Courses for Graduates and Advanced Undergraduates

ED 505 Public Area Schools 3 (3-0) fs
Prerequisite: Graduate status

Junior and community colleges, technical institutes, vocational schools, and branches of universities: Their development, status and prospects; policy and policy-making, clientele, purposes, evaluation programs, personnel, organization, administration, financing, facilities, research and development functions. Graduate staff

ED 506 Education of Exceptional Children 3 (2-2) f
Prerequisite: Six hours in education or psychology

Discussion of principles and techniques of teaching the exceptional child with major interest on the mentally handicapped and slow learner. Practice will be given in curiculum instruction for groups of children, individual techniques for dealing with retarded children in the average classroom. Opportunity for individual work with an exceptional child will be provided. Mr. Corter

ED 507 Analysis of Reading Abilities 3 (3-0) f
Prerequisite: Six hours in education or psychology

A study of tests and techniques in determining specific abilities; a study of reading retardation and factors underlying reading difficulties. Mr. Rust

ED 508 Improvement of Reading Abilities 3 (3-0) s
Prerequisite: Six hours of education or psychology

A study of methods used in developing specific reading skills or in overcoming certain reading difficulties; a study of methods used in developing pupil vocabularies and work analysis skills; a study of how to control vocabulary burden of reading material. Mr. Rust

ED 552 Industrial Arts in the Elementary School 3 (3-0) summer
Prerequisites: Twelve credits in education and permission of instructor

This course is organized to help elementary teachers and principals understand how tools and materials and industrial processes may be used to vitalize and supplement the elementary school children's experiences. Practical children's projects along with the building of classroom equipment. Graduate Staff

ED 563 Effective Teaching 3 (3-0) fs
Prerequisite: Twelve hours in education including student teaching

Analysis of the teaching-learning process; assumptions that underlie course approaches; identifying problems of importance; problem solution for effective learning; relationship of learning and doing; responsibility for learning; evaluation of teaching and learning; making specific plans for effective teaching. Mr. Scarborough

ED 595 See IA 595, Industrial Arts Workshop.

Courses for Graduates Only

ED 614 Modern Principles and Practices in Secondary Education 2 (2-0) fs
Prerequisite: Twelve hours in education

Foundations of modern programs of secondary education purposes, curriculum, organization, administration, and the place and importance of the high school in the community in relation to contemporary social force. Graduate Staff

ED 615 Introduction to Educational Research 3 (3-0) fs
Prerequisite: PSY 535 or equivalent

An introductory course for students preparing for an advanced degree. The purposes are: to assist the student in understanding the meaning and purpose of educational research and the research approach to problems; to develop students' ability to identify educational problems, and to plan and carry out research to solve these problems; to aid in the preparation of the research report. Special attention is given to tools and methods of research. Consideration is also given to the educator as a consumer of research. Mr. Chansky

ED 665 Supervising Student Teaching 3 (3-0) fs
Prerequisite: Twelve hours in education

A study of the program of student teaching in teacher education. Special consideration will be given the role of the supervising teacher including the following areas: planning for effective student teaching, observation and orientation, school community study, analysis of situation, evaluating student teachers and coordination with North Carolina State. Graduate Staff

ED 699 Research Credits by Arrangement
Prerequisites: Fifteen credits and permission of advisor

Individual research on a specific problem of concern to the student. Graduate Staff

DEPARTMENT OF ELECTRICAL ENGINEERING

GRADUATE FACULTY

Professors: George Burnham Hoadley, *Head*, William John Barclay, Arthur Raymond Eckels, William Damon Stevenson, Jr., *Graduate Administrator*, Frederick Joseph Tischer

Visiting Professor: Makoto Itoh

Adjunct Professors: Gerhard K. Megla, P. Gene Smith

Associate Professors: Norman Robert Bell, Robert Walter Lade, Edward George Manning, Wilbur Carroll Peterson

Adjunct Associate Professor: Erich Christian

Adjunct Assistant Professor: Larry King Monteith

The Department of Electrical Engineering offers the Master of Electrical Engineering, Master of Science, and the Doctor of Philosophy degrees. Graduate work in electrical engineering at the first-year or master's level is limited to one or two areas of specialization. In the more advanced study for the doctorate a comprehensive understanding of all fields of electrical engineering is required, and specialization appears in the research problem undertaken.

Advanced courses of a general and fundamental nature, such as

electrical network synthesis and electromagnetic waves, are required for those who plan to carry their advanced studies to the level of the doctorate. Minor sequences of study in advanced mathematics or physics are planned to fit the needs of individual students.

The laboratories of the department are equipped for research in electromagnetics, in electronic circuits, in automatic controls, and in solid-state devices. Active research is in progress, especially in the solid-state area where laboratory equipment makes possible the construction of a wide variety of solid-state devices.

Courses for Advanced Undergraduates

EE 401 Advanced Circuits and Fields 3 (2-2) f
Prerequisites: EE 202, MA 301
Required of Seniors in electrical engineering.

Transient analysis of electric circuits by the Laplace transform method, the study of transient and sinusoidal steady-state response in terms of poles and zeros of network functions.

EE 402 Advanced Circuits and Fields II 3 (2-2) fs
Prerequisites: EE 302, MA 301
Required of seniors in electrical engineering.

A study of classical electric and magnetic field theory and its application to problems of electrical engineering. Consideration of electrostatics, radiation, and guided waves.

EE 430 Essentials of Electrical Engineering 4 (3-3) f
Prerequisite: EE 301 or EE 332
Not available to undergraduates in electrical engineering.

Essential theory of electric circuits, including electron tubes, solid-state devices, transformers, and rotating machines as needed to supply the electrical background for instrumentation and control theory. Intended primarily for graduate students who do not have an electrical engineering undergraduate degree.

EE 431 Electronic Engineering 3 (2-3) f
Prerequisite: EE 314
Departmental elective for seniors in electrical engineering.

Comprehensive coverage of circuits and equipment using electronic devices; variable frequency effects; amplifiers, oscillators, modulators, detectors, wave-shaping circuits, generators of non-linear waveforms; basic pulse techniques; principles of electronic analogue computers. Emphasis on quantitative analysis and engineering design.

EE 432 Communication Engineering 3 (2-3) s
Prerequisite: EE 431
Departmental elective for seniors in electrical engineering.

Application of electronic circuits and equipment to radio and wire communication systems. Elements of complete systems, wave propagation, antennas, transmitters, receivers, television, radar, electronic navigation systems, noise, special applications.

EE 433 Electric Power Engineering 3 (2-3) f
Prerequisite: EE 305
Departmental elective for seniors in electrical engineering.

A study of industrial power supply and power factor correction; direct and alternating current motor characteristics, starting methods, dynamic braking and speed control; motor applications, and industrial control apparatus.

EE 434 Power System Analysis 3 (2-3) s
Prerequisites: EE 305
Departmental elective for seniors in electrical engineering.

Analysis of problems encountered in the long-distance transmission of electric power. Line parameters by the method of geometric mean distances. Circle diagrams, symmetrical components, and fault calculations. Elementary concepts of power system stability. Applications of digital computers to power system problems.

EE 435 Elements of Control 3 (2-3) f
Prerequisites: EE 314 and EE 305, or EE 430
Departmental elective for seniors in electrical engineering.

Introductory theory of open and closed loop control. Functions and performance requirements of typical control systems and system components. Dynamic analysis of error detectors, amplifiers, motors, demodulators, analogue components and switching devices. Component transfer characteristics and block diagram representation.

EE 438 Instrumentation in Nuclear Technology 3 (2-3) s
Prerequisites: Either EE 430 or EE 301, EE 314, MA 301
Departmental elective for seniors in electrical engineering.

Required course in nuclear engineering, instrumentation option. Radiation detectors, pulse amplifiers, pulse shapers, amplitude discriminators, counters, coincidence circuits.

EE 440 Fundamentals of Digital Systems 3 (3-0) f
Prerequisite: EE 314 or EE 430
Departmental elective for seniors in electrical engineering.

The basic theory of digital computation and control. Introduction to number systems, data handling, relay algebra, switching logic, memory circuits, the application of electronic devices to switching circuits and the design of computer control circuits.

EE 491 Electrical Engineering Senior Seminar 1 (0-2) f
Prerequisite: Senior standing
Required of seniors in electrical engineering.

Weekly meetings for the delivery and discussion of student papers on topics of current interest in electrical engineering.

Courses for Graduates and Advanced Undergraduates

EE 503 Linear Network Theory 3 (3-0) f
Prerequisites: EE 314, MA 301, B average in EE and MA

Analysis of linear networks, with emphasis on the system functions of the network in the frequency domain and response in the time domain.
Mr. Stevenson

EE 504 Introduction to Network Synthesis 3 (3-0) s
Prerequisite: EE 503

A development of the methods of network synthesis of one-port and two-port passive structures based on partial fraction techniques.
Mr. Stevenson

EE 506 Dynamical Analogies 3 (3-0) s
Prerequisites: EE 202 or EE 331; EM 301; MA 301; B average in EE, EM, and MA

A study of dynamic systems in various branches of engineering and science with emphasis on the similarities that exist among such integrated groups of devices. Analogous elements and quantities in these fields as determined from equations basic to each. Analytical formulation of system problems in acoustical, electrical, mechanical, and related fields and their

solution by analog methods. Use of electronic analog computers for the solution of system problems. Mr. Eckels

EE 507 Electromagnetics 3 (3-0) f
Prerequisites: EE 303, EE 314, MA 301, B average in EE and MA

Basic principles of electromagnetic field theory in vector analysis formulation, including static electric and magnetic fields, Maxwell's equations and applications to guided waves. Graduate Staff

EE 511 Electronic Circuits 3 (3-0) f
Prerequisites: EE 314 or EE 430, B average in EE and MA

Solid-state and vacuum electronic devices in amplifiers, feedback systems, oscillators, modulators, switching and wave-shaping circuits. Generation of nonlinear waveforms; electronic instruments; circuits basic to electronic computers. Use of complex frequency concepts to obtain generalized response. Communication, power, and industrial applications. Synthesis of circuits to satisfy system requirements. Mr. Barclay

EE 512 Communication Theory 3 (3-0) f
Prerequisites: EE 431 or EE 511, B average in EE and MA

The frequency and time domain, modulation, random signal theory, autocorrelation, basic information theory, noise, communication systems. Mr. Barclay

EE 516 Feedback Control Systems 3 (3-0) s
Prerequisites: EE 401, EE 435
Departmental elective for seniors in electrical engineering.

Study of feedback systems for automatic control of physical quantities such as voltage, speed, and mechanical position. Theory of regulating systems and servo-mechanisms. Steady state and transient responses. Evaluation of stability. Transfer function loci and root locus plots. Analysis using differential equation and operational methods. System compensation and introduction to design. Mr. Peterson

EE 517 Control Laboratory 1 (0-3) s
Corequisite: EE 516

Laboratory study of feedback systems for automatic control of physical quantities such as voltage, speed, and mechanical position. Characteristics of regulating systems and servo-mechanisms. The laboratory work is intended to contribute to an understanding of the theory developed in EE 516, Feedback Control Systems. Mr. Peterson

EE 520 Fundamentals of Logic Systems 3 (3-0) f
Prerequisites: EE 314 or EE 430, B average in EE and MA

A study of switching algebra, logic circuitry, systematic minimization, block diagrams, logic systems in computers, diode and transistor logic, symmetric functions, iterative networks, cascaded systems, sequential circuits, and pulsed operation. Mr. Bell

EE 521 Digital Computer Technology and Design 3 (3-0) s
Prerequisite: EE 520

A study of the internal organization and structure of digital systems including toggle circuits, gates and pulse circuitry. Analysis and synthesis of the major components of computers, including the logic section, counters, registers, storage devices, input-output, and control. Mr. Bell

EE 531, 532 Introduction to Solid-State Material Science 3 (3-0) fs
Prerequisites: PY 407, MA 301
Corequisite: ME 301

Elementary quantum mechanics, statistical mechanics, and Boltzmann transport theory are first presented as basic tools. The study of direct and

reciprocal Bravais lattices and of distributions of modes of lattice vibrations establishes the environment of electrons whose behavior in crystalline solids is then developed by presentations of free electron theory and the band theory. Behaviors of electrons and holes in both perfect and imperfect crystals are developed from basic classical and quantum mechanical principles. Mr. Matthews

EE 533 TRANSISTOR CIRCUITS 3 (3-0) f
Prerequisites: EE 302, EE 314, B average in EE and MA

A study of the application of transistors to linear and switching circuitry. The electrical response of such systems is considered in the light of certain physical characteristics of the transistor, in addition to the piecewise linear model. Device characteristics, temperature stability, cascaded amplifiers, and elementary switching circuits are treated. Mr. Manning

EE 591, 592 SPECIAL TOPICS IN ELECTRICAL ENGINEERING 3 (3-0) fs
Prerequisite: B average in technical subjects

A two-semester sequence to develop new courses and to allow qualified students to explore unusual areas. Graduate Staff

Courses for Graduates Only

EE 611, 612 ELECTRIC NETWORK SYNTHESIS 3 (3-0) fs
Prerequisite: EE 504

A study of modern network theory, with the emphasis on synthesis of both passive and active networks based on the work of Brune, Bode, Guillemin, Bott and Duffin, Darlington, Foster, Linville, Piloty, and many others. Both the realization problem and the approximation problem will be treated. Messrs. Christian, Hoadley

EE 613, 614 ADVANCED FEEDBACK CONTROL 3 (3-0) fs
Prerequisite: EE 516

An advanced study of feedback systems for the control of physical variables. Follower systems and regulators. Mathematical and graphical description of systems. Frequency response and root locus methods for compensation and design. Stability theory and performance criteria. The state variable concept. Continuous and discrete systems. Analysis of non-linear systems. Mr. Peterson

EE 615 ELECTROMAGNETIC WAVES 4 (3-3) s
Prerequisite: EE 507

Maxwell's equations applied to a study of the propagation of energy by electromagnetic waves. Vector and scalar retarded potentials, propagation in free space and material media, guided electromagnetic waves, common waveguides, skin effects, resonant cavities. Microwave network theory applied to measurement problems. Messrs. Barclay, Tischer

EE 616 MICROWAVE ELECTRONICS 4 (3-3) f
Prerequisite: EE 615

Frequency limitations of conventional electron tubes. Microwave power generation and control by interaction of electromagnetic fields with charged particles and molecular energy levels, and by non-linear reactances. Applications in klystrons, magnetrons, traveling-wave tubes, masers, and reactance amplifiers. Measurement problems and techniques in microwave region. Mr. Barclay

EE 617 PULSE, SWITCHING, AND TIMING CIRCUITS 3 (3-0) s
Prerequisites: EE 503, EE 512

Tube and transistor circuit techniques for the production, shaping, and control of nonsinusoidal wave forms. Fundamental circuits needed in pulse information systems, instrumentation, and computers. Mr. Barclay

EE 618 Antennas and Radiation 4 (3-3) s
Prerequisite: EE 615

Electromagnetic wave theory applied to radiating elements. Radiation from a small current element and multi-poles. Arbitrary radiation fields. Radiation characteristics, gain, beamwidth, sidelobe levels of antennas. The reciprocity theorem, scattering, effective aperture, and antenna temperature will be treated related to receiving type antennas. Mr. Tischer

EE 619 Guided Waves and Resonators 3 (3-0) s
Prerequisite: EE 615

A study related to guided waves and resonators with emphasis on microwaves and millimeter waves. The effect of boundaries on wave propagation and the means of guiding waves will be discussed from a general viewpoint beginning with electromagnetic waves. The analogies with other types of waves such as acoustic and plasma waves will be considered. Nonconventional waveguide concepts. General relationships for resonators and for their incorporation in communication systems will be derived.
Messrs. Barclay, Tischer

EE 623 Electronic Properties of Solid-State Materials 3 (3-0) f
Prerequisite: EE 532
Corequisite: PY 501

A study of the electronic properties of solids. Consideration of the motion of electrons in periodic potentials leads directly to the study of the band theory and its consequences on the electrical and magnetic properties of materials. Beginning with the Boltzmann transport equations a phenomenological description of charge-carrier flow is developed in terms of an effective mass tensor. Hot electron transport, radiative transition mechanisms and high field effects will be treated in some depth.
Mr. Monteith

EE 624 Electronic Properties of Solid-State Devices 3 (3-0) s
Prerequisite: EE 532

A study in detail of the terminal properties of a large class of solid-state devices. Boundary relationships at solid-state interfaces will be considered in considerable depth along with the determination of added carrier profiles in neutral and non-neutral bulk regions. The role of deep-lying traps on device performance will be treated as an introduction to a class of space-charge-limited devices. The present technology of device fabrication will be discussed and demonstrated. Mr. Lade

EE 641 Advanced Digital Computer Theory 3 (3-0) s
Prerequisite: EE 520

A study of the circuits and components of modern digital computers, including basic logic systems, codes, advanced systems of circuit logic, vacuum tube, transistor, and magnetic components. Memory devices, counters, converters, adders, accumulators, inputs, outputs, and computer control systems will be analyzed. Mr. Bell

EE 642 Automata and Adaptive Systems 3 (3-0) f
Prerequisite: EE 520

The study of neural nets in natural systems, artificial nerve nets, pattern-recognition devices, artificial intelligence, goal-directed behavior, self-repairing machines, the logic of automata, and adaptive Boolean logic.
Mr. Bell

EE 643 Advanced Electrical Measurements 3 (3-0) s
Prerequisites: EE 503, EE 431

A critical analysis of circuits used in electrical measurements, with special attention to such topics as balance convergence, effects of strays, sensitivity, the use of feedback in electronic devices, automatic measuring systems, and digital measuring systems. Mr. Hoadley

EE 645, 646 Advanced Electromagnetic Theory 3 (3-0) fs
Prerequisites: EE 615 or PY 503; MA 512

A comprehensive study of electromagnetic theory with emphasis on field theory applications. Charges in both uniform and accelerated motion, field equivalence principles, anisotropic media, ferrite media, variational methods for waveguide discontinuities, periodic structures including Floquet's theorem, integral transform and function-theoretical techniques, solid-state theory applied to quantum electronic devices. Mr. Itoh

EE 651 Statistical Communication Theory 3 (3-0) s
Prerequisite: EE 401 or EE 503; EE 512 or MA 541

Generalized waveform analysis including Fourier Transforms, correlation functions and other statistical descriptions of stationary random processes; manipulation of signal descriptions as affected by linear time-invarient networks; derivation of the optimum impulse response and transfer function of the general linear operator; optimum filter synthesis by the use of ortho-normal functions; problems to illustrate the applications of the theory. Mr. Smith

EE 653 Fundamentals of Space Communications 3 (3-0) f
Prerequisite: EE 615

An analytical study of communications related to space operations with emphasis on electromagnetics and antennas. Wave propagation along the transmission path in non-uniform and non-isotropic media. Ionospheric propagation and plasma sheath effects. Antenna characteristics for space operations on ground and on vehicles. Large surface radiators, phased arrays, and low noise structures. Vehicle-born antennas. Problems of signal transmission. Communications by lasers. Mr. Tischer

EE 691, 692 Special Studies in Electrical Engineering 3 (3-0) fs

This course provides an opportunity for small groups of advanced graduate students to study, under the direction of qualified members of the professional staff, advanced topics in their special fields of interest.
Graduate Staff

EE 695 Electrical Engineering Seminar 1 (1-0) fs
Prerequisite: Graduate standing in electrical engineering

A series of papers and conferences participated in by the instructional staff, invited guests, and students who are candidates for advanced degrees.
Mr. Eckels

EE 699 Electrical Engineering Research Credits by Arrangement
Prerequisites: Graduate standing in electrical engineering and permission of advisor
Graduate Staff

DEPARTMENT OF ENGINEERING MECHANICS

GRADUATE FACULTY

Professors: Patrick Hill McDonald, Jr., *Head*, Robert Alden Douglas, Adolphus Mitchell

Associate Professors: Maurice Hill Clayton, John Auert Edwards, Clarence Joseph Maday, *Graduate Administrator*, Daniel Shou-ling Wang

Assistant Professors: William Louis Bingham, John Frederick Ely, Edward Dewitt Gurley, Vernon Emerson Holt, Manohar Singh, James Baird Walker

The Department of Engineering Mechanics offers graduate programs leading to the Master of Science and the Doctor of Philosophy

degrees. The faculty of the department offers a broad range of graduate courses both for its own students seeking advanced degrees and for inclusion in the graduate programs of students in allied areas of engineering and in the physical and mathematical sciences.

Graduate studies in engineering mechanics embrace several broad areas including fluid mechanics, solid mechanics, continuum mechanics, dynamics, and structural mechanics. Each of these areas is of considerable importance in current research, to the extent that professional demands in these areas by space-related industry and governmental agencies is second only to those for the electronics specialties. Professional interests of the faculty are represented by courses devoted to the elastic and plastic behavior of solids, viscous and compressible fluid flow, the generalized behavior of matter when described as a continuum, and in sequences devoted to the theory of periodic and aperiodic vibrations and to space mechanics.

Courses for individual programs may be chosen rather broadly from the listings indicated, and special attention is directed to the reservoir of courses appropriate to mechanics studies, selected from closely allied engineering specialties. Beginning graduate students ordinarily will choose a program to encompass several of the major areas, thus establishing a broad base for subsequent studies at the advanced graduate level, usually concentrated about one particular area of research.

Graduate research in mechanics in any of the major areas outlined may follow the lines of either analytical or experimental investigations. The development of new research techniques for both types of endeavor is of prime concern to the field of mechanics and the laboratory complex of engineering mechanics includes a number of research laboratories. One of these is equipped for dynamic studies in viscoelasticity, one for research in fracture mechanics, and another for static and dynamic studies in stress concentration. Whether a student is inclined toward analytical or toward experimental investigations, he ordinarily will gain experience in both types of endeavor prior to his independent research activity.

Courses for Graduates and Advanced Undergraduates

EM 501, 502 CONTINUUM MECHANICS I, II 3 (3-0) fs
Prerequisites: EM 301, EM 303, ME 301, MA 405

The concepts of stress and strain are presented in generalized tensor form. Emphasis is placed on the discussion and relative comparison of the analytical models for elastic, plastic, fluid, viscoelastic, granular, and porous media. The underlying thermodynamic principles are presented, the associated boundary value problems are formulated and selected examples are used to illustrate the theory. Mr. Gurley

EM 503 THEORY OF LINEAR ELASTICITY 3 (3-0) f
Prerequisite: EM 301
Corequisite: MA 511 or MA 401

The fundamental equations governing the behavior of an elastic solid are developed in various curvilinear coordinate systems. Plane problems,

as well as the St. Venant Problem of Bending, Torsion & Extension of bars are covered. Displacement fields, stress fields, Airy & complex stress functions are among the methods used to obtain solutions. Mr. Ely

EM 504 Mechanics of Ideal Fluids 3 (3-0) f
Prerequisite: EM 304
Corequisite: MA 513

Basic equations of ideal fluid flow; potential and stream functions; vortex dynamics; body forces due to flow fields, methods of singularities in two-dimensional flows; analytical determination of potential functions; conformal transformations; free-streamline flows.
Messrs. Amein, Edwards, Holt

EM 505 Mechanics of Viscous Fluids I 3 (3-0) f
Prerequisite: EM 304
Corequisite: MA 532

Equations of motion of a viscous fluid (Navier-Stokes Equations); general properties of the Navier-Stokes equations; some exact solutions of the Navier-Stokes equations; boundary layer equations; some approximate methods of solution of the boundary layer equations; laminar boundary layers in axi-symmetric and three-dimensional flows; unsteady laminar boundary layers. Messrs. Amein, Edwards, Holt

EM 506 Mechanics of Compressible Fluids I 3 (3-0) f
Prerequisites: EM 304, ME 302
Corequisite: MA 532

Introduction to compressible fluid flow; isentropic, one-dimensional flow; Rayleigh and Fanno line flows; generalized one-dimensional flow; normal shock waves; introduction to multi-dimensional, compressible flow.
Mr. Edwards

EM 507 Systems Analysis 3 (3-0) f
Prerequisites: EM 301, EM 303, MA 511

A course in the design of engineering systems in which mechanics dominates. Mr. P. H. McDonald

EM 508 Systems Synthesis 3 (3-0) f
Prerequisite: EM 507

A course in the design of engineering systems in which mechanics dominates. Mr. P. H. McDonald

EM 509 Space Mechanics I 3 (3-0) f
Prerequisites: EM 302, EM 304
Corequisite: MA 511

The application of mechanics to the analysis and design of orbits and trajectories. Trajectory computation and optimization; space maneuvers; re-entry trajectories; interplanetary guidance. Messrs. Clayton, Maday

EM 510 Space Mechanics II 3 (3-0) f
Prerequisites: EM 509, MA 511

Continuation of EM 509. The analysis and design of guidance systems. Basic sensing devices; the characteristics of an inertial space; the theory of stabilized platforms; terrestrial inertial guidance.
Messrs. Clayton, Maday

EM 511 Theory of Plates and Shells 3 (3-0) f
Prerequisites: EM 301, MA 441

Bending theory of thin plates; geometry of surfaces and stresses in shells. Various methods of analysis are discussed and illustrated by problems of practical interest. Messrs. D. McDonald, Wang

EM 521 Properties of Solids 3 (3-0) f
Prerequisites: EM 301, MIM 201

Atomic and molecular principles are applied toward an introductory understanding of macroscopic material properties. The concept of the grand canonical ensemble average of atomic behavior is employed to unify the characterization and interrelationships of material properties. Finally, phenomenological behaviors and coupled effects are described within the continuum concept. Mr. Holt

EM 551 Advanced Strength of Materials 3 (3-0) f
Prerequisite: EM 301

Stresses and strains at a point; rosette analysis; stress theories, stress concentration and fatigue; plasticity; inelastic, composite and curved beams; prestress energy methods; shear deflections; buckling problems and column design; and membrane stresses in shells. Mr. Smith

EM 552 Elastic Stability 3 (3-0) s
Prerequisites: MA 301, MA 405, EM 551

A study of elastic and plastic stability. The stability criterion as a determinant. The energy method and the theorem of stationary potential energy. The solution of buckling problems by finite differences and the calculus of variations. The application of successive approximations to stability problems. Optimization applied to problems of aeroelastic and civil engineering structures. Mr. Gurley

EM 555, 556 Dynamics I, II 3 (3-0) fs
Prerequisites: EM 301, MA 405

The dynamics of particles and rigid bodies by the use of formulations of the laws of mechanics due to Newton, Euler, Lagrange, and Hamilton. Accelerated reference frames, constraints, Euler's angles, the spinning top, the gyroscope, precession, stability, phase space, and nonlinear oscillatory motion. Messrs. Clayton, Maday

Courses for Graduates Only

EM 601, 602 Unifying Concepts in Mechanics I, II 3 (3-0) fs
Prerequisite: PY 601

Generalized treatment of the fundamental equations and boundary value problems of continuous and non-continuous media. Use is made of contemporary developments in irreversible thermodynamics, statistical mechanics, and electro-dynamics to provide a unified foundation for the development of principles governing the dynamic and thermodynamic behavior of elastic, plastic and visco-elastic solids, viscous fluids and rheological media. Messrs. P. H. McDonald, Walker

EM 603 Theory of Elasticity II 3 (3-0) s
Prerequisite: EM 503
Corequisite: MA 513

An extension of EM 503 to include the Cauchy Integral methods for plane problems, three dimensional problems, variational methods, and the use of numerical methods. Mr. Ely

EM 604 Theory of Plasticity 3 (3-0) s
Prerequisite: EM 503

Analytical models are developed to represent the behavior of deformable solids in the plastic regime. Conditions of yielding and fracture which initiate and terminate plastic behavior are studied, with the special stress-strain relationships necessary in plasticity. The hyperbolic equations of slip-line fields characteristic of plane strain theory are developed. Mr. Singh

EM 611 Mechanics of Compressible Fluids II 3 (3-0) s
Prerequisite: EM 506

Continuation of EM 506; linearized theory of two-dimensional flow; method of characteristics for two-dimensional supersonic flow; oblique

shock waves; unsteady one-dimensional flow; shock-wave boundary layer interactions; transonic flow. Mr. Edwards

EM 612 Mechanics of Viscous Fluids II 3 (3-0) s
Prerequisite: EM 505

Continuation of EM 505; phenomenological theories of turbulence; turbulent flow in ducts and pipes; turbulent boundary layer with and without pressure gradient; compressible boundary layer; boundary layer control; free viscous flow. Messrs. Amein, Edwards

EM 641 Optical Mechanics 3 (2-3) s
Prerequisite: EM 402 or ME 516

Concepts of crystal optics applied to continua deformed statically or dynamically by mechanical or thermal loading; optical interference and its use as a measuring technique of absolute and relative retardations in various types of interferometers; relative retardation measurements; deformation measurements with diffraction gratings; Moire (mechanical) interference measurements. Mr. Bingham

EM 695 Experimental Methods in Mechanics 3 (2-3) s
Prerequisite: Permission of instructor

A study of specialized experimental techniques utilized in contemporary research in the areas of mechanics.
Messrs. Bingham, Douglas, Edwards, P. H. McDonald

EM 697 Seminars in Mechanics 1 (1-0) fs
Prerequisites: Graduate standing and permission of advisor

The discussion and development of theory relating to contemporary research in the frontier areas of mechanics. Messrs. Gurley, Maday

EM 698 Special Topics in Mechanics Credits by Arrangement

The study, by small groups of graduate students under the direction of members of the faculty, of topics of particular interest in various advanced phases of mechanics. Graduate Staff

EM 699 Research in Mechanics Credits by Arrangement

Individual research in the field of mechanics. Graduate Staff

DEPARTMENT OF ENTOMOLOGY

GRADUATE FACULTY

Professors: Edward Holman Smith, *Head,* Charles Henry Brett, Frank Edwin Guthrie, Walter Joseph Mistric, Jr., Robert Lamar Rabb, Clyde Fuhriman Smith, David Allan Young, Jr.

Professor Emeritus: Theodore Bertis Mitchell

Associate Professors: Richard Charles Axtell, William Vernon Campbell, Walter Carl Dauterman, Maurice High Farrier, Ernest Hodgson, Alexander Russell Main, Herbert Henry Neunzig, Thomas Jackson Sheets, Robert Takachi Yamamoto

Adjunct Assistant Professor: Edgar William Clark

The Department of Entomology offers graduate training leading to the Master of Science and Doctor of Philosophy degrees. The major areas for specialization are physiology, toxicology, ecology, behavior, nutrition, taxonomy, economic entomology, and medical and veterinary entomology.

The department is particularly well qualified to provide intensive training in areas requiring support by allied disciplines. The de-

partment is a participant in the program of the Institute of Biological Sciences (see page 17) and the departmental staff includes members of the faculty of physiology and biochemistry.

The extensive program of research, supported by federal granting agencies, industry and the University, provides opportunities for graduate training through actual participation in research.

Opportunities exist for training in both applied and fundamental phases of entomology. The applied phases are strongly influenced by the state's agriculture, in which tobacco, cotton, peanuts, livestock and forestry are important components. A cooperative arrangement with the School of Forestry provides for majors in forestry entomology.

Training in fundamental phases centers around programs such as the synthesis of lipids, comparative biochemistry, enzymology, toxicology, sensory behavior, and nutrition. The program in medical and veterinary entomology provides the opportunity for training in minor subjects at the School of Public Health at the University of North Carolina at Chapel Hill.

The research program is supported by a complex of modern departmental facilities, including seven recently completed biotron units, four laboratories for biochemical research, together with supporting greenhouses and rearing rooms. The extensive facilities of the Nuclear Reactor Project are also available for support of departmental projects. Other on-campus research facilities are available, as well as some others in the Research Triangle area.

The student is given wide latitude in the selection of his major and minor subjects from the varied programs offered. Stress is placed on development of independent thought, broad training in fundamentals and mastery of investigative techniques.

Courses for Advanced Undergraduates

ENT 401 LITERATURE OF BIOLOGY 1 (1-0) f
Prerequisite: Enrollment as upper-classman, undergraduate or graduate

A general course intended to acquaint students with literature problems of the scientist, mechanics of the library book classifications, bibliographies, abstract journals, taxonomic indexes, and preparation of scientific papers in agriculture, forestry, biology, and their subdivisions. Mr. Farrier

Courses for Graduates and Advanced Undergraduates

ENT 502 FUNDAMENTALS OF ENTOMOLOGY A 5 (2-6) f
Prerequisites: Twelve hours of biology, ENT 301 or ENT 312, or equivalent

An intensive treatment of the general external morphology of insects and a survey of the adults and immatures of the orders and principal families of insects with attention to their biology.
Messrs. Neunzig, Rabb, Young

ENT 503 FUNDAMENTALS OF ENTOMOLOGY B 5 (3-6) s
Prerequisites: Twelve hours of biology, nine hours of chemistry, ENT 301 or equivalent

Structure and morphological variations of organ systems in insects

including considerations of their histology and function. Sensory physiology and behavior will then lead into the basic elements of insect ecology.
Messrs. Campbell, Hodgson, Rabb, Young

ENT 504 Insect Morphology 3 (1-4) f
Prerequisite: ENT 502

Concerned with external morphology, primary and comparative phases, with emphasis on knowledge and techniques which can be applied to specific problems. (Offered 1967-68 and fall of alternate years.) Mr. Young

ENT 511 Systematic Entomology 3 (1-4) f
Prerequisite: ENT 301 or ENT 312 or equivalent

A somewhat detailed survey of the orders and families of insects, designed to acquaint the student with those groups and develop in the student some ability in the use of keys, descriptions, etc. (Offered 1966-67 and fall of alternate years.) Mr. Young

ENT 531 Insect Ecology 3 (2-2) f
Prerequisite: ENT 502 or ENT 503 or equivalent

The environmental relations of insects, including insect development, habits, distribution and abundance. (Offered 1967-68 and fall of alternate years.) Mr. Rabb

ENT 541 Immature Insects 2 (1-3) f
Prerequisite: ENT 502 or equivalent

An advanced study of the immature stages of selected orders of insects with emphasis on generic and specific taxa. Primary consideration is given to the larval stage, but a brief treatment of eggs and pupae is also included. (Offered 1966-67 and fall of alternate years.)
Mr. Neunzig

ENT 551 Fundamentals of Insect Control 3 (2-3) f
Prerequisites: ENT 312 or equivalent, twelve hours of chemistry, twelve hours of biology

The course is divided into two phases. The first deals with the basic causes of insect problems, an evaluation of the biological and economic aspects of insect attack, and the fundamental methods employed in insect control. The second part deals with the critical chemical, physical, and biological properties of compounds used for insect control. The material presented in the course is directed toward obtaining fundamental knowledge of the scientific principles underlying modern methods of protection of food, clothing, shelter, and health from arthropods. Mr. Guthrie

ENT 552 Applied Entomology 3 (1-4) s
Prerequisites: ENT 502, ENT 503, ENT 551

A course dealing with the organization of the field of applied entomology, the significance of other disciplines, research and extension methods, the concept of integrated control, and the solution of economic problems. (Offered 1965-66 and spring of alternate years.) Mr. Mistric

ENT 572 Forest Entomology 3 (2-2) s
Prerequisite: ENT 301 or ENT 312

A study of the methods of identification of forest pests, the factors governing their abundance, habits and control. (Offered 1965-66 and spring of alternate years.) Mr. Farrier

ENT 582 (ZO 582) Medical and Veterinary Entomology 3 (2-3) s
Prerequisites: ENT 301 or ENT 312 and ZO 581 or equivalent

A study of the morphology, taxonomy, biology and control of the arthropod parasites and disease vectors of man and animals. The ecology and behavior of vectors in relation to disease transmission and control will be emphasized. (Offered 1965-66 and spring of alternate years.)
Mr. Axtell

ENT 590 Special Problems Credits by Arrangement fs
Prerequisites: Graduate standing and permission of instructor

Original research on special problems in entomology not related to a thesis problem, but designed to provide experience and training in research.
Graduate Staff

ENT 592 Acarology 3 (2-2) s
Prerequisite: ENT 301 or ENT 312 or ZO 201

A systematic survey of the mites and ticks with emphasis on identification, biology and control of the more common and economic forms attacking material, plants and animals including man. (Offered 1966-67 and spring of alternate years.) Mr. Farrier

Courses for Graduates Only

ENT 602 Principles of Taxonomy 3 (1-4) s
Prerequisite: ENT 511

A course introducing the methods and tools used in animal taxonomy, designed to promote a better understanding of taxonomic literature, and provide a foundation for taxonomic research. (Offered 1966-67 and spring of alternate years.) Mr. Young

ENT 611 Biochemistry of Insects 3 (3-0) f
Prerequisite: CH 551 or equivalent

The biochemistry of insects will be considered with primary emphasis on intermediate metabolism. Aspects in which insects show specialization will be treated in greater detail. The comparative treatment used necessitates some consideration of other animal groups. (Offered 1966-67 and fall of alternate years.) Mr. Hodgson

ENT 622 Insect Toxicology 3 (2-3) s
Prerequisites: ENT 551, CH 551 or equivalent

The relation of chemical structure to insect toxicity, the mode of action of toxicants used to kill insects, the metabolism of insecticides in plant and animal systems, the selectivity within the cholinesterase inhibitors and other selective mechanisms, and the analysis of insecticide residues will be discussed. (Offered 1965-66 and spring of alternate years.)
Messrs. Dauterman, Guthrie

ENT 690 Seminar 1 (1-0) fs
Prerequisite: Graduate standing in entomology or closely allied fields

Discussion of entomological topics selected and assigned by seminar chairman. Graduate Staff

ENT 699 Research Credits by Arrangement fs
Prerequisite: Graduate standing in entomology or closely allied fields

Original research in connection with thesis problem in entomology.
Graduate Staff

DEPARTMENT OF EXPERIMENTAL STATISTICS

GRADUATE FACULTY

Professors: David Dickenson Mason, *Head,* Richard Loree Anderson, *Graduate Administrator,* Robert George Douglas Steel, *Associate Graduate Administrator,* Columbus Clark Cockerham, Arnold Herbert Edward Grandage, Robert John Hader, Don William Hayne, Henry Laurence Lucas, Jr., Francis Edward McVay, Robert James Monroe, Charles Harry Proctor, Jackson Ashcraft Rigney, Ralph Winston Stacy, Hubertus Robert van der Vaart, Oscar Wesler

Visiting Professor: MELVIN W. CARTER

Professor Emeritus: GERTRUDE MARY COX

Adjunct Professors: ALVA LEROY FINKNER, WALTER ANTON HENDRICKS, DANIEL GOODMAN HORVITZ

Associate Professors: HARVEY JOSEPH GOLD, WILLIAM JACKSON HALL, LAURENCE JAY HERBST, JOHN CLEMENT KOOP, JOHN OREN RAWLINGS, THOMAS DUDLEY WALLACE

Adjunct Associate Professors: SIDNEY ADDELMAN, WILLIAM ALEXANDER GLENN

Assistant Professors: BIBHUTI BHUSHAN BHATTACHARYYA, LAURENCE ALAN NELSON, JERRY ADOLPH WARREN

The Department of Experimental Statistics offers work leading to the Master of Science, Master of Experimental Statistics (nonthesis), and Doctor of Philosophy degrees. This department has a working arrangement with the Department of Biostatistics in the University of North Carolina's School of Public Health at Chapel Hill, whereby graduate students can major in experimental statistics and minor in the Division of Health Affairs. The Department of Experimental Statistics maintains a close liaison with the Department of (Mathematical) Statistics at Chapel Hill in order to strengthen the offerings in statistical theory. (See University of North Carolina at Chapel Hill courses listed below.) Introductory courses in the three departments are coordinated so that it is easy for a beginning statistics graduate student to transfer from one institution of the consolidated university to another. The three departments are affiliated with the Institute of Statistics (see page 17). Some doctoral theses in experimental statistics are directed by members of the graduate faculty of the two statistics departments at Chapel Hill.

Members of the department conduct research in biomathematics, non-linear systems, time series and spectral analysis, operations research, probability and stochastic processes, non-parametric inference, the development of statistical theory and techniques of design and analysis for surveys and experiments, and the development of physical and biological stochastic models. At least one staff member consults with researchers in each of the following fields and conducts his own research on statistical problems which are encountered: the various agricultural sciences, quantitative genetics, wildlife science (game and fish), industrial development and engineering, physical sciences, and social sciences and economics.

A graduate student who majors in experimental statistics may specialize in any one of these fields, with his minor in the associated departments, or with a strong mathematical background he may prefer to minor in mathematics or mathematical statistics. For the graduate student who wishes to minor in statistics, the department has developed a curriculum tailored to his needs. Many employers are offering added inducements for research personnel who have such a minor. The department cooperates with other graduate

departments in order to provide the type of courses needed for their students and to provide a staff to participate in their graduate programs.

A program of training in biomathematics at the doctoral and postdoctoral levels recently has been initiated in the Department of Experimental Statistics. This program requires that the student become well-grounded in four areas—mathematics, statistics, physical science, and some phase of biology. Fellowships and assistantships are available for doctoral students and several fellowships for post-doctorals. Mathematical biology and related areas are now developing rapidly and there is much opportunity for properly trained people.

The department is also cooperating with eight other departments at Raleigh and Chapel Hill in the development of a strong minor program in Operations Research at both the master's and doctoral levels. Details regarding the Operations Research graduate program are presented on page 169.

In addition to its consulting services, the department provides computer programming and other assistance to the Agricultural Experiment Station staff in close cooperation with the campus Computing Center. This work is currently augmented by a computer facility grant from the National Institutes of Health. The department also provides a desk calculator computing service for sets of data not economical to program for the digital computer. It furnishes several federal agencies, other states, and private concerns with research and consulting services on a contract basis. This work supplies live problems on which graduate students may acquire experience and maturity.

The Department of Experimental Statistics is located in a new building convenient to classroom and central library facilities. Ample space for graduate students is provided adjacent to faculty offices. A well-equipped desk computing laboratory is conveniently located in the graduate student area.

The Computing Center is in the process of being equipped with a Systems 360-Model 30 computer which will serve primarily as a tele-communications unit to the Triangle Universities Computation Center Systems 360-Model 75, a very large and fast computer. A smaller remote processing unit will be located in the statistics building, convenient for use in computer programming courses and student research.

The department has approximately twenty graduate fellowships and assistantships at stipends adjusted to the previous training and experience of the recipients. Included among these have been industrial fellowships, National Science Foundation traineeships, National Aeronautics and Space Agency fellowships, National Institutes of Health fellowships in biomathematics, and National Defense Education Act fellowships in econometrics jointly with the Department of Economics. Students who have a major in an applied field and who have a minimum of one year of calculus, or students

who have a major in statistics or mathematics are encouraged to apply for these fellowships and assistantships. Students who have no advanced calculus or matrix algebra are advised to make arrangements to take these courses in the summer prior to entrance in the graduate program. If a graduate assistant has a satisfactory course record, he can complete the requirements for the master's degree in two years (in less time if he takes courses during the summer). A graduate assistant with a master's degree in statistics can complete the requirements for the doctorate in two years. Graduate fellows may be able to complete the requirements in somewhat less time.

Most fields of research, development, production, and distribution are seeking persons trained in statistical theory and methods. The demand is equally strong from universities, agricultural and engineering experimental stations, national defense agencies, other federal agencies, and a wide variety of industrial concerns. There is a need for experimental statisticians with the master's degree as well as for those with the doctorate.

North Carolina State University is represented on the Committee on Statistics of the Southern Regional Education Board. This committee sponsors a continuing series of graduate summer sessions. In 1966, the host institution is tentatively scheduled to be the University of Georgia. Each of the sponsoring institutions will accept the credits earned by students in the summer session as residence credit. The courses are arranged to provide consecutive work in successive summers. Information regarding these courses may be obtained from the Department of Experimental Statistics or the Dean of the Graduate School.

Courses for Advanced Undergraduates

ST 421, 422 Introduction to Mathematical Statistics 3 (3-0) fs
Prerequisite: MA 202 or MA 212

Elementary mathematical statistics primarily for students not intending to take further work in theoretical statistics. Includes introduction to probability, common theoretical distributions, moments, moment generating functions, sampling distributions, (F, t, chi-square), elementary estimation, hypothesis testing concepts, decision theory concepts, and elements of general linear model theory. Staff

Courses for Graduates and Advanced Undergraduates

ST 501, 502 Basic Statistical Analysis 3 (3-0) fs
Prerequisite: ST 311 or equivalent or graduate standing

Basic concepts of statistics; random variables, distributions, statistical measures, estimation, tests of significance, analysis of variance, elementary design and sampling, factorial experiments, multiple regression, analysis of discrete data, and other topics. Intended primarily for statistics majors and Ph.D. minors and not intended as a service course for other departments. Mr. Steel

ST 511 Experimental Statistics for Biological Sciences I 3 (3-0) fs
Prerequisite: ST 311 or graduate standing

Basic concepts of statistical models and use of samples; variation, statistical measures, distributions, tests of significance, analysis of variance and elementary experimental design, regression and correlation, chi-square.
Messrs. Monroe, Rawlings

ST 512 Experimental Statistics for Biological Sciences II 3 (3-0) fs
Prerequisite: ST 511 or equivalent

Covariance, multiple regression, concepts of experimental design, factorial experiments, individual degrees of freedom, confounded factorial and split plot designs, and incomplete block designs.
Messrs. Monroe, Nelson

ST 513 Experimental Statistics for Social Sciences I 3 (3-0) f
Prerequisite: ST 311 or graduate standing

Basic concepts in collection and analysis of data. Variability of sample data, distributions, confidence limits, chi-square, t-test, analysis of variance, regression, correlation, analytic and descriptive surveys, experimental designs. Mr. McVay

ST 514 Experimental Statistics for Social Sciences II 3 (3-0) s
Prerequisite: ST 513 or equivalent

Extension of basic statistical concepts to social experiments and surveys; sampling from finite populations and estimating using unrestricted, stratified, systematic, and multistage selections; analysis of variance continued; multiple regression; covariance; experimental designs.
Mr. Proctor

ST 515, 516 Experimental Statistics for Engineers 3 (3-0) fs
Prerequisite: ST 361 or graduate standing

General statistical concepts and techniques useful to research workers in engineering, textiles, wood technology, etc. Probability, distributions, measurement of precision, simple and multiple regression, tests of significance, analysis of variance, enumeration data, sensitivity data, life testing experiments and experimental design. Mr. Hader

ST 541 See MA 541, Theory of Probability I. 3 (3-0) f

ST 542 See MA 542, Theory of Probability II. 3 (3-0) s

ST 551 Basic Statistical Inference 3 (2-2) s
Prerequisite: ST 541 (MA 541)
Corequisite: MA 405

Frequency distributions and moments; sampling distributions; introductory theory of point and interval estimation; tests of hypotheses.
Mr. Grandage

ST 552 Basic Theory of Least Squares and Variance Components 3 (2-2) f
Prerequisites: ST 551, MA 405

Theory of least squares; multiple regression; analysis of variance and covariance; experimental design models; factorial experiments; variance component models. Mr. Anderson

ST 571 (BS 571, MA 571) Biomathematics I 3 (3-0) f
Prerequisites: MA 301, MA 405 or equivalent

Linear time-invariant operators and their Laplace transforms, with a discussion of homogeneous and non-homogeneous linear differential equations and their analysis in time domain and frequency domain; applications to the study of input and output in biological systems; systems of linear and non-linear differential equations and their perturbation equations, especially with reference to the study of population dynamics and growth processes, stability of biological systems, and tracer kinetics. Mr. van der Vaart

ST 572 (BS 572, MA 572) Biomathematics II 3 (3-0) s
Prerequisites: ST 571, ST 541 (MA 541) or equivalent

Continuation of topics in ST 571. The general framework for mathematization of biological problems; deterministic and stochastic models; birth and death processes with applications to physiology and population dynamics; desirable features of mathematical models in biology.
Mr. van der Vaart

ST 591 Special Problems 1-3 Credits by Arrangement fs

Development of techniques for specialized cases, particularly in connection with thesis and practical consulting problems. Graduate Staff

U.N.C. ST 111 Methods of Mathematical Statistics I 3 (3-0) f
Prerequisite: Advanced calculus

Introductory treatment of special mathematical techniques of particular importance in probability and statistics, including topics from combinatorial mathematics, Fourier and Laplace transforms, contour integration, special inequalities and finite differences. Messrs. Leadbetter, Smith

U.N.C. ST 131 Elementary Probability 3 (3-0) f
Prerequisite: Advanced calculus

Fundamentals of probability theory and distribution theory essential for the study of mathematical statistics, including: axiomatic treatment of probability models, combinatorial probability, conditional probability and independence, random variables, distribution and density functions, moments and generating functions, combined random variables.
Mr. Kuebler

U.N.C. ST 132 Intermediate Probability 3 (3-0) s
Prerequisite: U.N.C. ST 131 or ST 134

Laws of large numbers, characteristic functions, and central limit theorems. Elements of stochastic processes and their applications, including random walks, Markov chains, recurrent events, Brownian motion, and elementary queueing theory. Mr. Smith

U.N.C. ST 134 Statistical Theory I 5 (4-2) f
Prerequisite: Advanced calculus

U.N.C. ST 131 plus regression and correlation theory, convergence and approximation, common distributions, functions of random samples, multinormal theory, and random normal sampling. Mr. Johnson

U.N.C. ST 135 Statistical Theory II 3 (3-0) s
Prerequisite: U.N.C. ST 131 or ST 134

Fundamentals of statistical inference and statistical decision theory, including: the decision and inference problem, sufficient statistics, point estimation (unbiasedness, Bayes and minimax methods, maximum likelihood and large sample theory), hypothesis testing, interval estimation, chi-square tests, and introduction to nonparametric, Bayesian, and sequential methods. Linear estimation, analysis of variance and regression are largely excluded. Mr. Johnson

U.N.C. ST 150 Analysis of Variance with Application to Experimental Designs 3 (3-0) s
Corequisite: U.N.C. ST 135

Linear estimation. Non-estimability. The best linear estimate and its variance. The Gauss-Markov theorem. Sums of squares. Analysis of variance and the generalized t and F tests. Unified mathematical theory of the intrablock analysis of incomplete block designs. Applications to balanced, lattice, partially balanced and Latin square designs.
Messrs. Bose, Chakravarti

U.N.C. ST 170 Order Statistics 3 (3-0) s
Prerequisite: U.N.C. ST 135 or equivalent

Distribution theory of order statistics. Moments, exact and approximate.

Estimation of location and scale parameters, censored data. Life-testing and scale parameters, censored data. Life-testing and reliability. Short-cut procedures, quality control. Tests for outliers and slippage. Multiple decision procedures based on order statistics. Asymptotic and extreme-value theory. Mr. David

Courses for Graduates Only

ST 606 (MA 606) Mathematical Programming II 3 (3-0) s
Prerequisite: IE 505 (MA 505)

This course is intended for those who desire to study linear and non-linear programming from an advanced mathematical point of view. Special attention will be paid to the theoretical and computational aspects of current research problems in the field of mathematical programming, including linear programming and game theory, theory of graphs, discrete linear programming, linear programming under uncertainty and non-linear programming. Mr. Bhattacharyya

ST 611, 612 Intermediate Statistical Theory 3 (3-0) fs
Prerequisites: ST 551, MA 512, MA 405

This course will provide the additional theory, above that of ST 551, needed for many advanced theory courses. Many of the topics of ST 551 will be developed more rigorously, with more attention paid to mathematical aspects. Advanced probability theory; limit theorems, distribution theory, multinormal distributions. Statistical decision theory, theory of estimation, confidence regions, theory of tests of hypothoses, sequential tests, non-parametric methods. Mr. Bhattacharyya

ST 613 Time Series Analysis I 3 (3-0) s
Prerequisite: ST 552

Statistical analysis of realizations of second order stationary random processes, and mathematical specifications of the underlying processes, with emphasis throughout on the spectrum. Discussions of applications are given to illustrate the theory and methods. Topics include second order stationary parent sequences, correlation analysis, autoregressive series, moving averages, hidden periodicities models, spectral analysis, estimation of the correlogram and the coefficients of autoregressive schemes, the periodogram, estimation of the spectral density; serial correlation theory, goodness-of-fit tests. Mr. Herbst

ST 614 Time Series Analysis II 3 (3-0) f
Prerequisites: ST 613, ST 542 (MA 542)

Cross-covariance analysis of two time series, cross-spectral analysis of two time series, estimation of co-spectral density, quadrature-spectral density, coherence and phase, interpretations and applications of coherence analysis, detection and estimation of periodicities in variances of time series, spectral representation theory for second order stationary processes, further discussion of spectral estimation. Mr. Herbst

ST 617, 618 (MA 617, 618) Measure Theory and Advanced Probability 3 (3-0) fs
Prerequisites: MA 512, MA 541 or equivalent

Modern measure and integration theory in abstract spaces, probability measures, random variables and expectations, conditional probability and conditional expectations, distribution functions, characteristic functions, modes of convergence, weak and strong laws of large numbers, central limit theorems and other limit laws, introduction to stochastic processes. Mr. Wesler

ST 619 (MA 619) Topics in Advanced Probability 3 (3-0) f
Prerequisites: ST 617, ST 618 (MA 617, MA 618)

Characteristic functions, infinitely divisible and stable laws, factorizations of probability distributions, law of iterated logarithm, random walks,

fluctuation theory, martingales, ergodic theory, Markov processes, the Poisson process, further topics in stochastic processes, applications.
Mr. Wesler

ST 621 Statistics in Animal Science 3 (3-0) f
Prerequisite: ST 502 or equivalent

Sources and magnitudes of errors in experiments with animals, experimental designs and methods of analysis adapted to specific types of animal research, relative efficiency of alternate designs, amount of data required for specified accuracy, student reports on selected topics. (Offered 1967-68 and fall of alternate years.) Mr. Lucas

ST 622 See ANS 622, Principles of Biological Assays. 3 (2-2) s

ST 623 Statistics in Plant Science 3 (3-0) f
Prerequisite: ST 502 or equivalent

Principles and techniques of planning, establishing, and executing field and greenhouse experiments. Size, shape and orientation of plots; border effects; selection of experimental material; estimation of size of experiments for specified accuracy; scoring and subjective tests; subsampling plots and yields for laboratory analysis. Mr. Mason

ST 626 (GN 626) Statistical Concepts in Genetics 3 (3-0) s
Prerequisite: GN 512
Corequisite: ST 502 or equivalent

Factors bearing on rates of change in population means and variances, with special reference to cultivated plants and domestic animals; selection, inbreeding, magnitude and nature of genotypic and non-genotypic variability; experimental and statistical approaches in the analysis of quantitative inheritance. Mr. Cockerham

ST 631 Theory of Sampling Applied to Survey Design 3 (3-0) f
Prerequisites: ST 422; ST 502 or equivalent

Principles for interpretation and design of sample surveys. Biases, variances and costs of estimators. Comparisons among simple random sample, ratio estimation, stratification, varying probabilities of selection, multistage, systematic and cluster sampling, double sampling. Response errors.
Mr. Proctor

ST 641 See RS 641, Statistics in Sociology. 3 (3-0) s

ST 651 See EC 651, Econometric Methods I. 3 (3-0) f

ST 652 See EC 652, Econometric Methods II. 3 (3-0) s

ST 671 Advanced Topics in Least Squares and Variance Components 3 (3-0) s
Prerequisites: ST 502 or equivalent, ST 552

Use of non-balanced designs to estimate variance components; comparison of estimators; problems with finite populations. Least squares procedures for non-standard conditions; unequal variances, correlated errors, non-additivity, measurement errors, non-normality. Functional relationships. Factorial experiments with continuous factor levels; incomplete blocks.
Mr. Anderson

ST 672 Special Advanced Topics in Statistical Analysis 3 (3-0) f
Prerequisites: ST 502 or equivalent, ST 552

Enumeration data; covariance; non-linear models; discriminant functions and other multivariate techniques. Mr. Monroe

ST 674 Advanced Topics in Construction and Analysis of Experimental Designs 3 (3-0) s
Prerequisites: ST 502 or equivalent, ST 552

Inter-block analysis of incomplete blocks designs, partially balanced

designs, confounding, data collected at several places and times, multiple factor designs, change-over trials, analysis of groups of means.
Mr. Addelman

ST 691 Advanced Special Problems 1-3 Credits by Arrangement fs
Prerequisites: ST 502 or equivalent, ST 552

Any new advance in the field of statistics which can be presented in lecture series as unique opportunities arise, including theory of sampling applied to survey design and analysis of linear models.
Graduate Staff, Visiting Professors

ST 694 Seminar 1 (1-0) fs
A maximum of two credits is allowed toward the master's degree, but any number toward the doctorate. Graduate Staff

ST 699 Research Credits by Arrangement fs
A maximum of nine credits is allowed toward the Master of Science degree; no limitation on credits toward the doctorate. Graduate Staff

U.N.C. ST 200 Applied Multivariate Analysis I 3 (3-0) f
Prerequisite: U.N.C. ST 135

Relations between multiple regression, analysis of variance, multivariate analysis and factor analysis. Tests with discriminant functions. The generalized Student ratio. Use of roots of determinantal equations. Classification problems. Distance and group constellations. (Offered 1966-67 and fall of alternate years.) Mr. Nicholson

U. N. C. ST 202 Methods of Operations Research 3 (3-0) f
Prerequisite: U.N.C. ST 135

Linear programming, theory of games, techniques for analyzing waiting lines and queues. Applied probability, recent developments, applications of results to specific problems. Case studies. Messrs. Nicholson, Smith

U.N.C. ST 212 Methods of Mathematical Statistics II 3 (3-0) s
Prerequisite: Advanced calculus

Measure and integration theory, with special reference to random variables, distribution functions, probability measures, and including Fubini's Theorem, the Radon-Nikodym Theorem, conditional probability, conditional expectation, and modes of convergence.
Messrs. Hall, Leadbetter, Smith

U.N.C. ST 220 Theory of Estimation and Hypothesis Testing 4 (4-0) f
Prerequisites: U.N.C. ST 132, ST 135, ST 212

Bayes procedures for estimation and testing. Minimax procedures. Sufficient statistics. Optimal unbiased estimators. Most powerful similar tests. Admissibility. Invariance. Confidence sets. Large sample theory.
Messrs. Hall, Hoeffding

U.N.C. ST 221 Sequential Analysis 2 (2-0) f
Prerequisites: U.N.C. ST 132, ST 135

Hypothesis testing and estimation when the sample size depends on the observations. Sequential probability ratio tests. Sequential design of experiments. Stochastic approximation. Messrs. Hoeffding, Johnson

U.N.C. ST 222 Nonparametric Inference 3 (3-0) s
Prerequisites: U.N.C. ST 132, ST 135, ST 212

Estimation and testing when the functional form of the population distribution is unknown. Rank and sign tests. Tests based on permutations of observations. Power of nonparametric tests. Optimum nonparametric tests and estimators. Nonparametric confidence intervals and tolerance limits.
Messrs. David, Hoeffding

U.N.C. ST 231 Advanced Probability 3 (3-0) f
Prerequisites: U.N.C. ST 132, ST 212

Advanced theoretic course, including: random variables and expecta-

tions, distributions and characteristic functions, infinitely divisible distributions, central limit theorems, laws of large numbers, and stable laws. (Offered 1966-67 and fall of alternate years.) Mr. Smith

U.N.C. ST 232 General Theory of Statistical Decision 3 (3-0) s
Prerequisites: U.N.C. ST 135, ST 212

Selected topics in the general theory of statistical decisions, based on the work of Abraham Wald. (Offered 1966-67 and spring of alternate years.) Mr. Hoeffding

U.N.C. ST 235 Stochastic Processes 3 (3-0) s
Prerequisites: U.N.C. ST 132, ST 212

Advanced theoretic course, including: separability of a process, processes with orthogonal random variables, Markov processes, martingales, and processes with independent increments. (Offered 1967-68 and spring of alternate years.) Mr. Smith

U.N.C. ST 251 Combinatorial Problems of the Design of Experiments 3 (3-0) f
Prerequisite: U.N.C. ST 150

Application of Galois fields and two dimensional finite geometries to the construction of complete sets of orthogonal Latin squares. Finite hyperspace geometries and balanced incomplete block designs obtainable from them. Factorial designs. Theory of confounding. Construction and analysis of symmetrical factorial designs with confounding. Construction and analysis of symmetrical fractionally replicated designs. Mr. Bose

U.N.C. ST 252 Information Theory 3 (3-0) f
Prerequisite: U.N.C. ST 132
Corequisite: U.N.C. ST 212

Transmission of information. Entropy. Simple message ensembles. Discrete sources. Transmission channels. Channel encoding and decoding. Encoding for binary symmetric channels. Encoding for discrete constant channels. (Offered 1967-68 and fall of alternate years.) Mr. Bose

U.N.C. ST 253 Error Correcting Codes 3 (3-0) s
Prerequisite: U.N.C. ST 251

Linear codes and their error correction capabilities. Some important linear codes. Linear switching circuits. Cyclic codes, Bose-Chaudhuri codes. Codes for burst error correction. Recurrent codes. Codes for checking arithmetic operations. (Offered 1967-68 and spring of alternate years.) Mr. Bose

U.N.C. ST 254 Special Topics in Design of Experiments I 3 (3-0) f
Prerequisite: U.N.C. ST 150

Response surface designs. Conditions for rotatability. Construction and analysis of rotatable designs of the second and third order. Interblock analysis. General analysis of covariance. Missing plot techniques. (Offered 1966-67 and fall of alternate years.) Mr. Bose

U.N.C. ST 255 Special Topics in the Design of Experiments II 3 (3-0) s
Prerequisite: U.N.C. ST 251

Combinatorial properties and construction of balanced, group divisible and partially balanced designs. Impossibility proofs. Orthogonal Latin squares of non-prime power orders. Orthogonal arrays. Asymmetrical fractionally replicated designs. (Offered 1966-67 and spring of alternate years.) Mr. Bose

U.N.C. ST 260 Multivariate Analysis 3 (3-0) f
Prerequisites: U.N.C. ST 135, Matrices

Characterization and properties of a multivariate normal distribution, random samples from this distribution. Tests and confidence intervals re-

lated to the hypotheses of equality of two or more dispersion matrices against various types of alternatives. Multivariate analysis of variance, covariance and regression, under a linear model with fixed effects against Association between subsets of a multivariate normal set including several kinds of independence. Factor analysis. Staff

U.N.C. ST 261 Advanced Multivariate Analysis 3 (3-0) s
Prerequisite: U.N.C. ST 260

Distribution problems connected with the tests and confidence intervals discussed in U.N.C. ST 260. The properties, in terms of statistical inference, of the tests and confidence intervals against different classes of alternatives. Advanced multivariate analysis of variance under a linear model with random or mixed-type effects against various kinds of alternatives. Multivariate designs for problems of MANOVA and for patterned dispersion matrices. Problems of classification. Some applications. Staff

U.N.C. ST 262 Multifactor Multiresponse Experiments with Responses not Necessarily Normal 3 (3-0) f
Prerequisite: U.N.C. ST 150
Corequisite: U.N.C. ST 260

Unstructured and structured factors. Unstructured and structured responses based on a single or a product multinomial or hypergeometric distribution. Hypotheses against alternatives, analogous to those discussed in U.N.C. ST 260 for the multivariate normal case. Large sample tests and the associated confidence intervals. One or more structured responses based on a continuous c.d.f., and the appropriate hypotheses against alternatives in this situation. Exact and asymptotic tests. Staff

U.N.C. ST 263 Advanced Multifactor Multiresponse Experiments with Responses not Necessarily Normal 3 (3-0) s
Prerequisite: U.N.C. ST 262

Properties, in terms of statistical inference, of the tests and confidence intervals discussed in U.N.C. ST 262. Generalization of univariate or multivariate analysis of variance to the case of normal error and random effects not necessarily normal. Design and analysis of factorial experiments with one or more normal response-types, treated as a problem in structured hypothesis. Relation to the classical design and analysis of factorial experiments and to those based on the response surface approach. Staff

U.N.C. ST 300, 301 Seminar in Statistical Literature 1 (1-0) fs
Prerequisite: U.N.C. ST 135 Mr. Johnson

U.N.C. ST 310, 311 Seminar in Theoretical Statistics 3 (3-0) fs
Prerequisite: U.N.C. ST 135 Staff

U.N.C. ST 321, 322 Special Problems 3 (3-0) fs
Prerequisite: Permission of instructor Staff

U.N.C. ST 331, 332 Advanced Research 3 (3-0) fs
Prerequisite: Permission of instructor Staff

DEPARTMENT OF FOOD SCIENCE

GRADUATE FACULTY

Professors: William Milner Roberts, *Head*, Leonard William Aurand, Thomas Nelson Blumer, John Lincoln Etchells, Maurice William Hoover, Ivan Dunlavy Jones, Marvin Luther Speck, Frederick Gail Warren

Associate Professors: Thomas Alexander Bell, Daniel Fromm, Victor Alan Jones, Albert Ernest Purcell, Fred Russell Tarver, Jr.

Assistant Professors: Robert J. Bingham, Francis Fredrick Busta, William Younts Cobb, Raghunath Singh Dahiya, Henry Pridgen Fleming, Harold Everette Swaisgood, William Alexander Brown Thomson, William Wood Walters, Jr.

The Department of Food Science was established at North Carolina State in 1961 to integrate the various scientific disciplines basic to the preparation, processing, packaging, and distribution of foods. Programs of graduate study leading to the Master of Science and Doctor of Philosophy degrees are offered. In order to pursue graduate study in the field of food science, the student must possess adequate information in the fundamentals of the area in which he expects to specialize. The student's undergraduate education should have prepared him in mathematics, chemistry, biological and physical sciences, as well as in the humanities and language skills.

In the area of food chemistry, the student can conduct research and study in peroxidation of lipids in foods, flavor and color chemistry, protein denaturation, and various problems of biophysical chemistry.

Engineering aspects of food science are offered in the principles of automation and industrial engineering in food plant operations.

The field of food products technology is concerned with the development of new foods and the improved quality of existing foods.

Food microbiology is designed to offer study and research in the fundamental principles of microbiology involved in promoting growth of microorganisms essential to the manufacture of various foods, and the control of unwanted microorganisms in foods.

The department's physical facilities include research laboratories equipped for chemistry, engineering and microbiology, and processing facilities and equipment for dairy, fruit, vegetable, poultry, peanut, seafood and meat products.

The Department of Food Science maintains close liaison with the faculties of supporting departments. Depending on the area chosen by the student for his major interest, he will have strong support for his minor from faculties in chemistry, economics, engineering, genetics, microbiology, and statistics.

A graduate program in food science and sanitation is offered by the Department of Food Science and the Department of Environmental Sciences and Engineering of the University of North Carolina at Chapel Hill. This program is designed to provide an enrichment in environmental health to graduate students majoring in food science at Raleigh; similarly, it provides an enrichment in food science to graduate students majoring in environmental sciences and engineering at Chapel Hill.

Courses for Advanced Undergraduates

FS 400 Foods and Nutrition 3 (3-0) s
Prerequisite: CH 220

A study of the health of an individual as related to food and the ability of his body to use food. Evaluation of normal diets and factors that pro-

mote optimal nutrition throughout life, and the application of biochemistry to utilization of foods.

FS 401 Market Milk and Related Products 3 (2-3) f

Principles of processing, distribution and quality of fluid milk and related products.

FS 403 Ice Cream and Related Frozen Dairy Foods 3 (2-3) s
Prerequisite: FS 401

Choice, preparation and processing of ingredients and freezing of ice cream and other frozen desserts.

FS 404 (PO 404) Poultry Products 3 (2-3) f
Prerequisites: CH 101, BS 100

Selection, processing, grading and packaging poultry meat and eggs. Factors involved in preservation of poultry meat and eggs.

FS 410 Food Products Evaluation 3 (2-3) s
Prerequisite: ST 361 or equivalent

A comprehensive study of problems encountered in new food product development with consumer acceptance. A study of the nature of sensory responses with emphasis on taste, smell and appearance (color) as related to foods; design and methodology of small and large consumer panel testing; and the application of appropriate mathematical procedures to food acceptance testing and methodology.

Courses for Graduates and Advanced Undergraduates

FS 502 Food Chemistry 3 (3-0) f
Prerequisite: CH 220 or CH 221

The basic composition, structure and properties of food, and the chemistry of changes occurring during processing and utilization of food. Interpretation and integration of widely published data in the food field with basic principles of chemistry. Mr. Aurand

FS 503 Food Analysis 3 (1-6) s
Prerequisites: CH 215, CH 351, FS 502

A study of the principles, methods and techniques necessary for quantitative physical and chemical analyses of food and food products. Results of analysis will be studied and evaluated in terms of quality standards and governing regulations. Mr. Swaisgood

FS 505 (MB 505) Food Microbiology 3 (2-3) f
Prerequisites: MB 401, MB 402

The relationship of habitat to the occurrence of microorganisms on foods; environmental factors affecting the growth of various microorganisms in foods; microbiological action in relation to food spoilage and food manufacture; physical, chemical and biological destruction of microorganisms in foods; methods for microbiological examination of food-stuffs; and public health and sanitation bacteriology.
Messrs. Busta, Speck

FS 506 (MB 506) Advanced Food Microbiology 3 (0-9) s
Prerequisite: FS 505 or equivalent

Ecology and physiology of microorganisms important in the manufacture and deterioration of various classes of foods; the identification of representative species of such microorganisms isolated from natural environments; principles of nutrition, symbiosis and bacteriophage activity in culture maintenance for food production.
Messrs. Busta, Speck

FS 521, 522 Technology of Fruit and Vegetable Products 3 (2-3) fs
Prerequisites: MB 401, MB 402

Comprehensive treatment of principles and methods of preservation of fruits and vegetables, including studies of commercial plant operations, and visits to food processing plants. Mr. Hoover

FS 590 Food Science Seminar 1 (1-0) s
Prerequisites: Senior or graduate standing and permission of instructor

A review and discussion of scientific articles, progress reports in research and special problems of interest. Graduate Staff

FS 591 Special Problems in Food Science 1 to 3 fs
Prerequisites: Senior or graduate standing and permission of instructor

Analysis of scientific, engineering and economic problems of current interest in foods. The scientific appraisal and solution of a selected problem. The problems are designed to provide training and experience in research. Graduate Staff

Courses for Graduates Only

FS 690 Seminar in Food Science 1 (1-0) fs

Preparation and presentation of scientific papers, progress reports of research and special topics of interest in foods. Graduate Staff

FS 691 Special Research Problems in Food Science Credits by Arrangement

Directed research in a specialized phase of food science designed to provide experience in research methodology and philosophy. Graduate Staff

FS 699 Research in Food Science Credits by Arrangement

Original research preparatory to the thesis for the Master of Science or Doctor of Philosophy degree. Graduate Staff

SCHOOL OF FORESTRY

GRADUATE FACULTY

Professors: Richard J. Preston, Jr., *Dean*, Roy M. Carter, Charles B. Davey, John W. Duffield, Eric L. Ellwood, Benjamin A. Jayne, Joe O. Lammi, T. Ewald Maki, Alfred J. Stamm, Bruce J. Zobel

Visiting Professor: David W. French

Adjunct Professors: Louis John Metz, Stanley Kendrick Suddarth

Associate Professors: Aldos C. Barefoot, Jr., Arthur W. Cooper, Ellis B. Cowling, Maurice H. Farrier, James W. Hardin, Clarence A. Hart, Charles S. Hodges, Jr., Thomas O. Perry, LeRoy C. Saylor

Assistant Professor: Gene Namkoong

Adjunct Assistant Professor: Elmer George Kuhlman

The School of Forestry, through its departments of Forest Management and Wood Science and Technology, offers graduate work leading to the master's and the Doctor of Philosophy degrees. Two types of master's programs are available to the graduate student.

The professional degrees of Master of Forestry and Master of Wood Technology are offered for students interested in advanced applications of fundamental principles to the specialized fields of forestry. The course program emphasizes professional specialization. There is no language requirement and the thesis requirement is optional.

The degree of Master of Science is offered for the student who contemplates a career in research, in teaching, or both. The course of study for this degree provides for a comprehensive knowledge of forest management or wood technology and furnishes the training essential for successful research in these fields. Training is broadly-based and emphasizes fundamental science. There is both a thesis and language requirement.

The Doctor of Philosophy degree is available to forestry students of high intellectual capacity who can demonstrate the ability to undertake original research and scholarly work at the highest levels.

Candidates for the master's degree fall under one of the following categories:

1. Students with a bachelor's degree in forestry from a school of recognized standing. These students may secure the master's degree in one year.

2. Students with a bachelor's degree, other than in forestry, from a college, university, or scientific school of high standing. These students may secure the master's degree in two academic years provided they have the requirements in botany, chemistry, and mathematics required in the freshman and sophomore years of the curricula. Candidates for the degree of Master of Forestry or Master of Science in forest management who do not hold an undergraduate degree in forestry must start their program with the summer camp.

3. Students not possessing a bachelor's degree may earn, through proper selection of courses, a Bachelor of Science degree in one of the forestry curricula at the end of the fourth year and a master's degree in forestry or wood technology at the end of the fifth year.

Study and training in forestry, the profession of managing forest lands and using the products of these lands, prepares young people for careers in the forests, in the wood-using industry, in business, government, and education.

Nearly 60 percent of the southeastern region of the United States is in forest lands that produce 38 percent of the nation's lumber and 56 percent of the pulpwood. The economy and well-being of the South depend greatly on efficient utilization of forest products.

New wood-using industries have moved into the southeast on an unprecedented scale and existing industries employ more than 650,000 persons and have an annual output in excess of $6,000,000,000. These industries, together with government agencies, demand a large number of technically trained men with a wide variety of specialized training.

Forestry provides wide and diversified employment opportunities that can be grouped under the headings of management and utilization. Forest management generally leads to outdoor jobs concerned with operating public or private forest properties. Utilization jobs usually lead to private industry concerned with manufacturing processes or merchandising.

Examples of specific types of employment include:

Management—forest managers, forest or park rangers, forest wildlife managers, watershed managers, forest recreationists, forest soils specialists, forest entomologists or pathologists, extension foresters, consulting foresters, municipal foresters, research workers.

Utilization—plywood technologists, logging engineers, mill managers, gluing technologists, pulp technologists, finishing supervisors, preservation technologists, merchandisers, production specialists, research workers, teachers, wood chemists, quality control managers, technical salesmen, wood technologists.

Graduate preparation is essential for specialists, who are needed in many fields. Training through the master's degree is almost a requirement for men entering college teaching and public or industrial research. State and federal agencies as well as forest industries are employing research investigators at unprecedented levels. The demand for men with advanced degrees in forestry has far exceeded the supply for many years.

The School of Forestry is now housed in three modernly equipped buildings on the west side of the campus. An additional $1,500,000 facility has been authorized and is under development. Two specialized buildings house regional programs:

The **Brandon P. Hodges Wood Products Laboratory** is one of the largest and most completely equipped laboratories for training and research in wood technology. This structure houses machining, gluing, finishing, preserving, testing and research laboratories, as well as a sawmill, dry kiln and veneer lathe.

The **Reuben B. Robertson Pulp and Paper Laboratory** is unique to the South. The building contains wood preparation, chemistry, pulping, testing and coloring laboratories as well as digesters and a small paper machine.

The School of Forestry with five research and demonstration forests containing more than 80,000 acres has excellent facilities for field instruction. The Hofmann forest on the coastal plain and the Hill, Schenck, Hope Valley and Goodwin forests in the Piedmont provide a wide variety of forest types. The permanent Slocum summer camp for sophomores in forest management is located on the Hill forest.

Research in the School of Forestry is organized as a department of forestry research in the Agricultural Experiment Station. The faculty of the school includes thirty-six teaching and research scientists. The research program has developed into impressive proportions, currently operating on an annual budget in excess of $500,000. This program, developed on a broad base, is designed to meet the immediate and future needs of forest owners and wood-using industries. A substantial part of the program is in the area of basic research—seeking new knowledge and endeavoring to achieve breakthroughs which will open the way for new products, techniques and markets. Basic research is a major university re-

sponsibility. Applied research also has an important role in the research program—providing answers to today's problems and a base for immediate improvement and efficiency.

The research program is divided into two major areas closely interrelated: (1) forest production, protection, and recreation in the Department of Forest Management, and (2) the processing and utilization of wood and fiber for products such as lumber, veneer, manufactured wood products including furniture, pulp and paper, and wood chemicals, all in the Department of Wood Science and Technology.

A number of research assistantships are available.

Courses for Advanced Undergraduates

FOR 403 Paper Process Analysis 3 (0-6) f

Manufacture of several types of papers with particular attention to stock preparation, sizing, filling and coloring. The finished products are tested physically and chemically and evaluated from the standpoint of quality and in comparison with the commercial products they are intended to duplicate.

FOR 404 Management Analysis 3 (1-6) s

Application of management, logging, silvicultural and utilization practices on assigned areas. Each student must make a forest survey of an individual area and submit a report.

FOR 405 Forest Inventory 3 (1-6) s

Timber estimating and data compilation.

FOR 411, 412 Pulp and Paper Unit Processes 3 (3-0) fs

Principles of operation, construction and design of process equipment in the pulp and paper industry.

FOR 413 Paper Properties and Additives 4 (1-9) f

Physical, chemical and microscopical examination of experimental and commercial papers and evaluation of the results in terms of the utility of the product tested.

FOR 422 Forest Products 3 (3-0) f
Prerequisites: FOR 202, CH 220

The source and method of obtaining derived and manufactured forest products other than lumber.

FOR 423 Logging and Milling 3 (2-3) f

Timber harvesting and transportation methods, equipment and costs; safety and supervision; manufacturing methods; log and lumber grades.

FOR 432 Merchandising Forest Products 2 (2-0) f

Principles and practices in the distribution and marketing of the products obtained from wood; organization and operation of retail, concentration and wholesale outlets.

FOR 434 Wood Operations I 3 (2-3) f
Prerequisites: FOR 301, FOR 302

Organization of manufacturing plants producing wood products including company organization, plant layout, production planning and control. Analysis of typical manufacturing operations in terms of process equipment, size and product specification. The organization and operation of wood products markets.

FOR 435 Wood Operations II 3 (2-3) s
Prerequisites: FOR 301, FOR 302

The application of the techniques of operations analysis to management decision making in the wood products field. Choice of products to manufacture. Allocation of production resources. Development of product distribution systems.

FOR 441 Design of Wood Structures 3 (2-3) f
Prerequisite: EM 211

Strength and related properties of commercial woods; standard A.S.T.M. strength tests; toughness; timber fastenings; design of columns; simple, laminated and box beams; trusses and arches.

FOR 444 Introduction to Quality Control 3 (2-3) s
Prerequisite: ST 361

A study of methods used to control quality of manufactured wood products. Control charts for variable and attributes. Acceptance sampling techniques.

FOR 451 Forest Recreation Policy and Management 2 (2-0) f

Analysis of outdoor recreation policies in the United States and their significance to forest land management; evaluation of the recreation potential of forests and other wild lands; examination of the relationships between federal, state, and local government and private enterprise in providing outdoor recreation opportunities.

FOR 461 Paper Converting 1 (1-0) s

A survey of the principal processes by which paper and paper board are fabricated into the utilitarian products of everyday use.

FOR 462 Artificial Forestation 2 (1-3) s

Production collection, extraction, and storage of forest tree seeds; nursery practice; field methods of planting.

FOR 463 Plant Inspections 1 (0-3) s

One week inspection trips covering representative manufactures of pulp paper and papermaking equipment.

FOR 471 Pulping Process Analysis 4 (1-9) f

Preparation and evaluation of the several types of wood pulp. The influence of the various pulping and bleaching variables on pulp quality are studied experimentally and these data evaluated critically.

FOR 481 Pulping Processes and Products 2 (2-0) s
Prerequisites: FOR 202, CH 220

Wood pulp manufacturing processes and equipment; wall insulation and container board products; manufacture of roofing felts; pulp products manufacturing; resin and specialty products, lignin and wood sugar products.

FOR 482 Pulp and Paper Mill Management 2 (2-0) s

A survey of the economics of the pulp and paper industry is followed by a study of the work of the several departments of a paper mill organization and the functions of the executives who administer them.

FOR 491, 492 Senior Problems Credits by Arrangement

Problems selected with faculty approval in the areas of management or technology.

Courses for Graduates and Advanced Undergraduates

FOR 511 Silviculture 3 (3-0) s
Prerequisites: FOR 361, BO 421

The principles and application of intermediate and reproductive methods of cutting; controlled burning, silvicides, and other methods of hardwood control. The application of silvicultural methods in the forests of the United States. Mr. Duffield

FOR 512 Forest Economics 3 (3-0) f
Prerequisites: FOR 372, EC 201

Economics and social value of forests; supply of, and demands for forest products; land use; forestry as a private and a public enterprise; economics of the forest industries. Mr. Lammi

FOR 513 Tropical Woods 2 (1-3) s
Prerequisites: FOR 203, FOR 301

Structure, identification, properties, characteristics and use of tropical woods, especially those used in plywood and furniture. Mr. Barefoot

FOR 521, 522 Chemistry of Wood and Wood Products 3 (2-3) fs
Prerequisites: FOR 202, CH 215, CH 426, PY 212

Fundamental chemistry and physics of wood and wood components; pulping principles; electrical and thermal properties. Mr. Stamm

FOR 531, 532 Forest Management 3 (2-3) fs
Prerequisite: FOR 372
Corequisite: FOR 511

Management of timber lands for economic returns; the normal forest taken as the ideal; the application of regulation methods to the forest. Mr. Bryant

FOR 533 Advanced Wood Structure and Identification 2 (1-3) f
Prerequisite: FOR 202

Advanced microscopic identification of the commercial woods of the United States and some tropical woods; microscopic anatomical features and laboratory techniques. Mr. Barefoot

FOR 553 Forest Photogrammetry 2 (1-3) s
Prerequisites: FOR 372, FOR 531

Interpretation of aerial photographs, determination of density of timber stands and area mapping. Mr. Lammi

FOR 571 Advanced Forest Mensuration 3 (2-2) s
Prerequisites: ST 311, FOR 372

Study of cyclical variation in growth of individual trees and stands; analysis of stand structures in even-aged versus all-age stands; general concepts of growing stock levels on yields; evaluation of growth prediction methods.

FOR 572 Forest Policy 3 (3-0) f
Prerequisites: EC 201, FOR 219
Corequisite: FOR 531

Analysis of the forest policies of the United States and selected foreign countries; criteria for their evaluation; appraisal of current policies and alternatives. Mr. Lammi

FOR 591 Forestry Problems Credits by Arrangement
Prerequisite: Senior or graduate standing

Assigned or selected problems in the fields of silviculture, logging, lumber manufacturing, pulp technology, or forest management. Graduate Staff

FOR 599 Methods of Research in Forestry Credits by Arrangement
Prerequisite: Senior or graduate standing

Research procedures, problem outlines, presentation of results; consideration of selected studies by forest research organizations; sample plot technique. Graduate Staff

Courses for Graduates Only

FOR 603 Technology of Wood Adhesives 3 (3-0) f or s
Prerequisites: CH 425, CH 426, FOR 433

The fundamentals of adhesives as applied to wood-to-wood and wood-to-metal bonding. Technology of adhesives. Preparation and use of organic adhesives. Testing of adhesives and evaluation of quality of adhesives and bonded joints. Mr. Hart

FOR 604 Timber Physics 3 (3-0) f or s
Prerequisite: FOR 441

Density, specific gravity and moisture content variation affecting physical properties; physics of drying at high and low temperatures; thermal, sound, light and electrical properties of wood. Messrs. Ellwood, Hart

FOR 605 Design and Control of Wood Processes 3 (3-0) f or s
Prerequisite: FOR 604

Design and operational control of equipment for processing wood.
Mr. Ellwood

FOR 606 Wood Process Analysis 3 (3-0) f
Prerequisites: FOR 512, FOR 604

Analysis of wood process through the solution of comprehensive problems involving the physics of temperature and moisture relations.
Mr. Ellwood

FOR 607 Advanced Quality Control 3 (3-0) s
Prerequisites: FOR 606, ST 515

Advanced statistical quality control as applied to wood processing.
Mr. Hart

FOR 611 Forest Genetics 3 (3-0) f or s
Prerequisites: GN 411 and permission of instructor

Application of genetic principles to silviculture, management and pulp utilization. Emphasis is on variations in wild populations, on the bases for selection and desirable qualities and on fundamentals of controlled breeding. Messrs. Saylor, Zobel

FOR 691 Graduate Seminar 1 (1-0) f or s
Prerequisite: Graduate standing in forestry or closely allied fields

Presentation and discussion of progress reports on research, special problems and outstanding publications in forestry and related fields.
Graduate Staff

FOR 692 Advanced Forest Management Problems Credits by Arrangement
Prerequisite: Graduate standing

Directed studies in forest management. Graduate Staff

FOR 693 Advanced Wood Technology Problems Credits by Arrangement

Selected problems in the field of wood technology. Graduate Staff

FOR 699 Problems in Research Credits by Arrangement
Prerequisite: Graduate standing

Specific forestry problems that will furnish material for a thesis.
Graduate Staff

DEPARTMENT OF GENETICS

GRADUATE FACULTY

Professors: Thurston Jefferson Mann, *Head*, Carey Hoyt Bostian, Daniel Swartwood Grosch, Warren Durwood Hanson, Ken-ichi Kojima, Dale Frederick Matzinger, Robert Harry Moll, Harold

Frank Robinson, Benjamin Warfield Smith, Stanley George Stephens

Associate Professors: Lawrence Eugene Mettler, LeRoy Charles Saylor, Anastasios Christos Triantaphyllou

Assistant Professors: Charles Sandford Levings, III, Gene Namkoong, Robert Hilton Schaible, Charles William Stuber

Associate Members of the Genetics Faculty

Professors: Jay Lawrence Apple, Ernest Oscar Beal, Charles Aloysius Brim, James Ferris Chaplin, Fred Derward Cochran, Columbus Clark Cockerham, John W. Duffield, Dan Ulrich Gerstel, Edward Walker Glazener, Walton Carlyle Gregory, Paul Henry Harvey, Frank Lloyd Haynes, Jr., Teddy Theodore Hebert, Guy Langston Jones, Kenneth Raymond Keller, James Edward Legates, Philip Arthur Miller, Richard Robert Nelson, Lyle Llewellyn Phillips, Daniel Townsend Pope, Hamilton Arlo Stewart, Donald Loraine Thompson, Nash Nicks Winstead, Bruce John Zobel

Associate Professors: Frank Bradley Armstrong, William Lowery Blow, Will Allen Cope, Emmett Urcey Dillard, Donald Allen Emery, Gene John Galletta, James Walker Hardin, Joshua A. Lee, Thomas O. Perry, Nathaniel T. Powell, John O. Rawlings, Odis Wayne Robison, David H. Timothy

Assistant Professors: Eugene J. Eisen, George Richard Gwynn, Charles F. Murphy, Earl A. Wernsman

Graduate study under direction of the genetics faculty may enable the student to qualify for the Master of Science or the Doctor of Philosophy degrees. A candidate for the master's degree must acquire a thorough understanding of genetics and its relation to other biological disciplines and must present a thesis based upon his own research. In addition to a comprehensive knowledge of his field, a candidate for the doctorate must demonstrate his capacity for independent investigation and scholarship in genetics.

At North Carolina State University there are no sharp divisions along departmental lines between theoretical and applied aspects of genetics research. The members and associate members of the genetics faculty are located in ten different departments of the Schools of Agriculture and Life Sciences, Forestry, and Physical Sciences and Applied Mathematics. They are studying an extremely wide range of genetic problems and are utilizing not only the "classic" laboratory material (*Drosophila, Habrobracon,* maize, and mice) but also farm animals and agricultural and horticultural plants of the region. A student has, therefore, a wide choice of research problems in any of the following fields: cytology and cytogenetics, microbial and biochemical genetics, physiological and irradiation genetics, forest genetics, population genetics, and the application of quantitative genetics to breeding methodology.

The offices and laboratories of the department are located in Gardner Hall with greenhouse facilities adjacent to the building. A genetics garden for use in the intensive research with plants and teaching functions is located three miles from the departmental offices. The departmental staff and the associate faculty members in Animal Science, Biochemistry, Botany, Crop Science, Horticultural Science, Microbiology, Poultry Science, Plant Pathology, Experimental

Statistics, and Forest Management are most fortunate in being able to draw upon the extensive facilities of the North Carolina Agricultural Experiment Station.

Courses for Advanced Undergraduates

GN 411 The Principles of Genetics 3 (3-0) fs
Prerequisite: BS 100

An introductory course. The physical and chemical basis of inheritance; genes as functional and structural units of heredity and development; qualitative and quantitative aspects of genetic variation. Mr. Schaible

GN 412 Elementary Genetics Laboratory 1 (0-2) fs
Prerequisite or corequisite: GN 411

Experiments and demonstrations to provide an opportunity to gain practical experience in crossing and classifying a variety of genetic materials including two generations of *Drosophila*. Mr. Schaible

Courses for Graduates and Advanced Undergraduates

GN 503 See ANS 503, Genetic Improvement of Livestock. 3 (2-3) f

GN 512 Genetics 4 (3-2) f
Prerequisite: GN 411

Intended for students desiring more thorough and detailed training in fundamental genetics with some attention to physiological aspects. Students conduct individual laboratory problems. Mr. Grosch

GN 513 Cytogenetics I 4 (3-2) f
Prerequisite: GN 512 or equivalent

The chromosomes as vehicles of heredity. Mitosis and meiosis as bases of genetic stability and recombination. Structural and numerical aberrations and their effect upon the breeding systems of plants and animals. Interspecific hybrids and polyploids. Lectures and laboratory.
Messrs. Galletta, Gerstel

GN 520 See PO 520, Poultry Breeding. 3 (3-0) f

GN 532 (ZO 532) Biological Effects of Radiations 3 (3-0) s
Prerequisite: ZO 103 or equivalent

Qualitative and quantitative effects of radiations (other than the visible spectrum) on biological systems, to include both morphological and physiological aspects in a consideration of genetics, cytology, histology, and morphogenesis. Mr. Grosch

GN 540 (ZO 540) Evolution 3 (3-0) f
Prerequisite: GN 411

The facts and theories of evolution in plants and animals. The causes and consequences of organic diversity. (Offered 1966-67 and alternate years.) Mr. Smith

GN 541 See CS 541, HS 541, Plant Breeding Methods. 3 (3-0) f

GN 542 See CS 542, HS 542, Plant Breeding Field Procedures. 2 (0-4) summer

GN 550 Experimental Evolution 3 (3-0) s
Prerequisites: GN 512, GN 513 or equivalent

Experimental evolution deals primarily with micro-evolutionary processes examined at the inter- and intra-specific population level. A review of the results from experimental population studies and analyses of natural populations concerning variation patterns and adaptation, natural selection, polymorphism, introgression, population breeding structure, isolating mechanism, etc., is made and interpreted in relation to Neo-Darwinian concepts of the origin of species. Mr. Mettler

GN 561 Biochemical and Microbial Genetics 3 (3-0) f

The course will include the development of the fields of biochemical and microbial genetics and will emphasize both the techniques and concepts utilized in current research. Mr. Armstrong

Courses for Graduates Only

GN 603 See ANS 603, Population Genetics in Animal Improvement. 3 (3-0) f

GN 607 (PP 607) Genetics of Fungi 3 (3-0) f
Prerequisites: GN 512 or equivalent, permission of instructor

Review of major contributions in fungus genetics with emphasis on principles and theories that have evolved in recent development. (Offered 1966-67 and alternate years.) Mr. Nelson

GN 611 See FOR 611, Forest Genetics. 3 (3-0) s

GN 613 See CS 613, Plant Breeding Theory. 3 (3-0) s

GN 626 See ST 626, Statistical Concepts in Genetics. 3 (3-0) s

GN 631 Mathematical Genetics 3 (3-0) f
Prerequisites: GN 512; ST 511 or equivalent

History of mathematical biology, role of mathematical concepts in the development of genetic science, theory of genetic recombination, dynamics of genetic population. (Offered 1965-66 and alternate years.)
Mr. Kojima

GN 633 Physiological Genetics 3 (3-0) s
Prerequisite: GN 512

Recent advances in physiological genetics. Attention will be directed to literature on the nature and action of genes, and to the interaction of heredity and environment in the expression of the characteristics of higher organisms. Mr. Grosch

GN 641 Colloquim in Genetics 2 (2-0) fs
Prerequisites: Graduate standing, permission of instructor

Informal group discussion of prepared topics assigned by instructor.
Graduate Staff

GN 691 Seminar 1 (1-0) fs
Prerequisite: Graduate standing

GN 695 Special Problems in Genetics 1-3 credits fs
Prerequisites: Advanced graduate standing, permission of instructor

Special topics designed for additional experience and research training.
Graduate Staff

GN 699 Research Credits by Arrangement
A maximum of six credits is allowed for the master's degree; by arrangement for the doctorate.

Original research related to the student's thesis problem.
Graduate Staff

GEOLOGICAL ENGINEERING

(For a listing of graduate faculty and departmental information see Department of Mineral Industries, page 159.)

Courses for Advanced Undergraduates

MIG 415 Mineral Exploration and Evaluation 3 (2-3) s
Prerequisites: MIG 440, MIG 452

Application of the principles of geology, geophysics, and geochemistry to the discovery and evaluation of mineral deposits. Design of mineral exploration and development programs based on knowledge of the unique thermodynamic, geochemical, and tectonic features that control mineral formation and concentrations in well known mining districts, especially those yielding ferrous, base, and precious metals. Review of economic and technological factors governing the value of mineral deposits.

MIG 440 Endogenic Materials and Processes 4 (3-3) s
Prerequisites: MIG 120 or MIG 220, MIG 331

Minerals, rocks and mineral deposits that are formed at high temperatures and pressures by crystallization or solidification of molten magma, or by solid state recrystallization of older rocks. Application of principles of thermodynamics and of phase-rule chemistry, and the results of modern high pressure-temperature laboratory research on the stability fields of crystalline phases, to an understanding of igneous and metamorphic rocks. Identification, classification, occurrence, origin, and economic value of the principal igneous and metamorphic rocks.

MIG 452 Exogenic Materials and Processes 4 (3-3) f
Prerequisites: MIG 120 or MIG 220, MIG 331

Identification, classification, geologic occurrence, origin, and economic value of minerals, rocks, and mineral deposits formed by physical, chemical, and biological processes at low temperatures and pressures at and near the earth's surface. Hydrodynamics of sediment transport and deposition, settling velocities and size sorting, chemical and biochemical precipitation from aqueous solutions, principles of division of stratified terranes into natural units, correlation of strata, identification of depositional environments, and facies analysis.

MIG 461 Engineering Geology 3 (3-0) f
Prerequisite: MIG 120 or MIG 220

The application of geologic principles to engineering practice; analysis of geological factors and processes affecting specific engineering projects.

MIG 462 Geological Surveying 3 (1-6) s
Prerequisites: MIG 351, MIG 440, MIG 452
Required of seniors in geological engineering.

Methods of field observation and use of geologic surveying instruments in surface and underground work; representation of geologic features by maps, sections and diagrams. Lectures, laboratories, and field work.

MIG 465 Geological Field Procedures 6 summer
Prerequisite: MIG 351 or special permission

A six week summer field course. Practical field procedures and instruments commonly used to procure geologic data for evaluating mineral deposits, solving engineering problems involving earth materials, and drawing scientific conclusions. Observation of geologic phenomena in their natural setting. Large and intermediate scale geologic mapping of surface features and large scale mapping underground in mine workings.

MIG 472 Elements of Mining Engineering 3 (2-3) f
Prerequisite: MIG 120 and junior standing in geological engineering

Introduction to mining; surface and underground methods of development and production; explosives, drilling and blasting; ore loading, transport, and hoisting; drainage and ventilation; mine surveying and sampling; fire assaying; mining law, organization, administration, and safety. Lectures, laboratory and field inspections.

Courses for Graduates and Advanced Undergraduates

MIG 522 Petroleum Geology 3 (3-0) s
Prerequisite: MIG 452

Properties, origin and modes of occurrence of petroleum and natural gas. Geologic and economic features of the principal oil and gas fields, mainly in the United States. Mr. Leith

MIG 552 Exploratory Geophysics 3 (2-3) s
Prerequisites: MIG 351, PY 202

Fundamental principles underlying all geophysical methods; procedure and instruments involved in gravitational, magnetic, seismic, electrical, and other methods of studying geological structures and conditions. Spontaneous potential, resistivity, radioactivity, temperature, and other geophysical logging methods. Study of applications and interpretations of results. Mr. Leith

MIG 563 Applied Sedimentology 3 (3-0) s
Prerequisite: MIG 452

Advanced treatment of the geological aspects of erosion and sediment transport and deposition, especially as related to engineering works, and to land and water utilization. Analysis of physical, mineralogical, and some chemical properties of sediments and sedimentary rocks; interpretatation of these properties in terms of depositional basins and environments. Mr. Leith

MIG 565 Hydrogeology 3 (3-0) f
Prerequisite: MIG 452

Occurrence and sources of surface and subsurface water. Relationship of surface water to subsurface water. Rock properties affecting infiltration, movement, lateral and vertical distribution, and quality of ground water. Determination of permeability, capacity, specific yield, and other hydraulic characteristics of aquifers. Principles of well field design. Legal aspects of water supplies. Mr. Welby

MIG 567 Geochemistry 3 (3-0) f
Prerequisite: CH 231 or CH 433

The quantitative distribution of elements in the earth's crust, the hydrosphere, and the atmosphere. Application of the laws of chemical equilibrium and resultant chemical reactions to natural earth systems. Geochemical applications of Eh-pH diagrams. Geochemical cycles. Isotope geochemistry. Mr. Brown

MIG 571, 572 Mining and Mineral Dressing 3 (2-3) fs
Prerequisite: MIG 472

Principles of the mineral industry; mining laws, prospecting, sampling, development, drilling, blasting, handling, ventilation and safety; administration, surveying, assaying; preparation, beneficiation and marketing. Graduate Staff

MIG 581 Geomorphology 3 (3-0) f
Prerequisite: MIG 452

A systematic study of land forms and their relations to processes and stages of development and adjustment to underlying structure. Lectures, map interpretations, and field trips. Mr. Welby

MIG 593 Advanced Topics in Geological Engineering 1 to 6 fs
Prerequisite: Permission of staff

Special study of some advanced phases of geological engineering.
Graduate Staff

Courses for Graduates Only

MIG 611, 612 Advanced Economic Geology 3 (3-0) fs
Prerequisites: MIG 440, MIG 452

Detailed study of the origin and occurrence of specific mineral deposits.
Mr. Brown

MIG 632 Microscopic Determination of Opaque Minerals 3 (0-6) s
Prerequisite: MIG 331

Identification of metallic, opaque minerals in polished sections by physical properties, etch reactions and microchemical tests. Laboratories.
Mr. Brown

MIG 642 Advanced Petrography 3 (1-4) s
Prerequisites: MIG 331, MIG 440

Application of the petrographic microscope to the systematic study of the composition and origin of rocks; emphasis on igneous and metamorphic rocks.
Mr. Parker

MIG 695 Seminar 1 (1-0) fs
Prerequisite: Graduate standing

Scientific articles, progress reports and special problems of interest to geologists and geological and mining engineers discussed.
Graduate Staff

MIG 699 Geological Research Credits by Arrangement
Prerequisite: Permission of instructor

Lectures, reading assignments, and reports; special work in geology to meet the needs and interests of the students. Thesis problems.
Graduate Staff

DEPARTMENT OF HISTORY

GRADUATE FACULTY

Professors: Ralph Weller Greenlaw, *Head,* Marvin L. Brown, Jr., Stuart Noblin
Associate Professors: Burton Floyd Beers, Murray Scott Downs

No graduate degrees are offered in history at North Carolina State University. Graduate programs leading to advanced degrees in this field are offered at the University of North Carolina at Chapel Hill. The courses listed below are eligible for graduate credit when they form a part of an approved graduate program in other departments, and work in history may serve as a minor field.

Courses for Advanced Undergraduates

HI 401 Russian History 3 (3-0) f
Prerequisite: Three hours of history or permission of department

This course presents the major trends in Russian social, political, economic, and cultural history, with emphasis on the nineteenth and twentieth centuries. USSR policy is studied in relation to the full sweep of Russian history.

HI 404 Asia and the West 3 (3-0) s
Prerequisite: Three hours of history or permission of department

A history of Asia from 1800 to the present with emphasis on Asian nationalism and conflict with the imperial powers.

HI 407 France Since the Revolution 3 (3-0) f
Prerequisite: Three hours of history or permission of department

An examination of the major trends in French history since the downfall of Napoleon I. Cultural, economic, social, and intellectual threads are stressed as well as the political. The ways in which France has been a seedbed for new movements in Europe are particularly noted.

HI 412 Recent United States History 3 (3-0) fs
Prerequisite: Three hours of history or permission of department

A study of the main currents in American political, economic, social, and diplomatic history of the twentieth century.

HI 422 History of Science 3 (3-0) fs
Prerequisite: Three hours of history or permission of department

A study of the evolution of science from antiquity to the present with particular attention given to the impact of scientific thought upon selected aspects of western civilization. The course provides a broad perspective of scientific progress and shows the interrelationship of science and major historical developments.

HI 424 American Intellectual History 3 (3-0) s
Prerequisite: Three hours of history or permission of department

An investigation of the convictions and ideals that have had consequences in American history. Ideas about society, economies, religion, education, politics, and government are included in order to explain how Americans have viewed their experience in the New World. Emphasis is placed on the interrelationship between the expression of these ideas and their historic context.

HI 427 European Intellectual History Since 1800 3 (3-0) f
Prerequisite: Three hours of history or permission of department

Covering the period since the French Revolution this course examines major trends in European thought influencing the course of history. Special attention is given to the development of the social sciences. The growth of a distinct intellectual class and the role of its ideas in European political and social life is emphasized.

HI 462 (ED 462) History of Education 3 (3-0) s
Prerequisite: Three hours of history or permission of department

The course traces the development of educational institutions and practices and analyzes the ideas and influence of educational innovators and critics. Approximately equal time is given to each of the following areas: the Greeks to the Reformation, Modern Europe, and the United States.

Courses for Graduates and Advanced Undergraduates

HI 534 (RS 534) Agricultural Organizations and Movements 3 (3-0) s
Prerequisite: Three credits in American history, American government, sociology or a related social science

A history of agricultural organizations and movements in the United States and Canada principally since 1865, emphasizing the Grange, the Farmers' Alliance, the Populist revolt, the Farmers' Union, the Farm Bureau, the Equity societies, the Nonpartisan League, cooperative marketing, government programs, and present problems. Mr. Noblin

DEPARTMENT OF HORTICULTURAL SCIENCE

GRADUATE FACULTY

Professors: Fred Derward Cochran, *Head*, Walter Elmer Ballinger, Frank Lloyd Haynes, Jr., John Mitchell Jenkins, Jr., Clarence Leslie McCombs, Daniel Townsend Pope

Associate Professors: Thomas Franklin Cannon, Gene John Galletta, Leaton John Kushman, Roy Axel Larson, Conrad Henry Miller

The Department of Horticultural Science offers the Master of Science degree and the professional degree, Master of Horticulture. Evidence of high scholastic achievement in the basic biological sciences is particularly desirable for students who expect to study for the Master of Science degree in horticulture.

The department has excellent greenhouses, laboratories, cold storages, and access to adequate field plots for graduate training in crop production, plant propagation, nutrition and physiology, biochemistry, morphology, plant breeding, cytology, and post-harvest physiology. The greenhouse range covers over 30,000 square feet and has twenty-one sections, each containing individual temperature and light control equipment. Laboratory facilities include four analytical laboratories, two cytological and anatomical laboratories, one soil testing laboratory for greenhouse control, one radio-isotope laboratory, and one landscape and floral design laboratory. Post-harvest facilities include, additionally, fourteen controlled temperature storage rooms and grading, washing and packaging equipment. These combined facilities provide a wide variety of opportunities in basic and technical research in the horticultural field. An extensive and varied assortment of plant materials is available for use in graduate programs.

The wide variations in climate and soils in North Carolina, from the coast to the mountains, make possible the study of plant responses under these varied conditions. Land and facilities for horticultural research are available on ten of the outlying stations located throughout North Carolina.

The opportunities for employment after advanced training include teaching and research in state and privately endowed educational institutions; research and regulatory positions with the United States Department of Agriculture, both foreign and domestic; extension specialists and county agents; research, production and promotional work with food, chemical, and seed concerns; orchard, nursery and greenhouse supervisors; and inspectors and quality control technologists.

Courses for Advanced Undergraduates

HS 411 Nursery Management . 3 (2-3) f
Prerequisites: BS 100, SSC 200

The principles and practices involved in the production, management and marketing of field-grown and container-grown nursery plants. Field trips will be taken. (Offered 1966-67 and fall of alternate years.)

HS 421 Fruit Production 3 (2-3) f
Prerequisites: BS 100, SSC 200

A study of identification, adaptation, and methods of production and marketing of the principal tree and small fruits. Modern practices as related to selection of sites, nutritional requirements, management practices, and marketing procedures will be discussed.

HS 432 Vegetable Production 3 (2-3) f
Prerequisites: BS 100, SSC 200

A study of the origin, importance, distribution, botanical relationships, and principles of production and marketing of the major vegetable crops.

HS 441 Floriculture I 3 (2-3) f
Prerequisites: BS 100, SSC 200

The scope and importance of the commercial flower industry; the basic principles and practices involved in the production and marketing of flowers grown in the greenhouse and in the field. (Offered 1967-68 and fall of alternate years.)

HS 442 Floriculture II 3 (2-3) s
Prerequisites: BS 100, SSC 200

Principles and methods of production of commercial flower crops in the greenhouse and in the field, including fertilization, moisture, temperature, and light relationships, insect and disease control, and marketing of cut flowers and pot plants. (Offered 1965-66 and spring of alternate years.)

HS 471 Arboriculture 3 (2-2) s
Prerequisites: BS 100, SSC 200

A study of the principles and practices in the care and maintenance of ornamental trees and shrubs, such as pruning, fertilization, control of insects and diseases, and tree surgery. Field trips will be taken. (Offered 1966-67 and spring of alternate years.)

HS 481 Breeding of Horticultural Plants 3 (2-2) f
Prerequisite: GN 411

The application of genetics and other biological sciences to the improvement of horticultural crops.

Courses for Graduates and Advanced Undergraduates

HS 541 (GN 541, CS 541) Plant Breeding Methods 3 (3-0) f
Prerequisites: GN 512, ST 511 recommended

An advanced study of methods of plant breeding as related to principles and concepts of inheritance. Messrs. Haynes, Timothy

HS 542 (GN 542, CS 542) Plant Breeding Field Procedures 2 (0-4) summer
Prerequisite: HS 541 (CS 541, GN 541)

Laboratory and field study of the application of various plant breeding techniques and methods used in the improvement of economic plants.
Graduate Staff

HS 552 Growth of Horticultural Plants 3 (2-3) s
Prerequisite: BO 421

A study of the effect of nutrient-elements, water, light, temperature and growth substances on growth and development of horticultural plants.
Messrs. Fish, Miller

HS 562 Post-Harvest Physiology 3 (3-0) s
Prerequisite: BO 421

A study of chemical and physiological changes that occur during hand-

ling, transportation, and storage which affect the quality of horticultural crops. Consideration will be given to pre- and post-harvest conditions which influence these changes. Messrs. Ballinger, McCombs

HS 599 RESEARCH PRINCIPLES Credits by Arrangement
Prerequisite: Permission of instructor

Investigation of a problem in horticulture under the direction of the instructor. The students obtain practice in experimental techniques and procedures, critical review of literature and scientific writing. The problem may last one or two semesters. Credits will be determined by the nature of the problem, not to exceed a total of four hours.
Graduate Staff

Courses for Graduates Only

HS 613 See CS 613, PLANT BREEDING THEORY. 3 (3-0) s

HS 621 METHODS AND EVALUATION OF HORTICULTURAL RESEARCH 3 (3-0) f
Prerequisite: Graduate standing

Principles and methods of research in the field of horticulture and their application to the solution of current problems. Critical study and evaluation of scientific publications. Compilation, organization, and presentation of data. Mr. Cochran

HS 691 SEMINAR 1 (1-0) fs
Prerequisite: Graduate standing
Required of all horticultural science graduate students.

Presentation of scientific articles and special lectures. Students will be required to present one or more papers. Graduate Staff

HS 699 RESEARCH Credits by Arrangement
Prerequisites: Graduate standing in horticulture, permission of advisory committee chairman
A maximum of six credits is allowed toward the Master of Science degree; no limitation on credits in doctoral program.

Original research on specific problems in fruit, vegetable, and ornamental crops. Graduate Staff

DEPARTMENT OF INDUSTRIAL ARTS

GRADUATE FACULTY

Associate Professors: TALMAGE BRIAN YOUNG, *Head*, CARL ALBERT MOELLER
Visiting Professor: ELBERT W. TISCHENDORF
Professor Emeritus: IVAN HOSTETLER

The Department of Industrial Arts offers graduate work leading to the Master of Science degree and the Master of Education degree. Industrial arts majors may select one or two minors in such fields as guidance, psychology, sociology, or school administration.

Graduate level professional and laboratory courses are provided to assure a well-rounded program of graduate studies.

Teaching and graduate assistantships are available each year for experienced teachers interested in pursuing graduate work. Loans are also available through the National Defense Education Act.

Holders of master's degrees in Industrial Arts Education are much in demand for supervisory and teaching positions in the public schools and colleges.

Courses for Graduates and Advanced Undergraduates

IA 510 Design for Industrial Arts Teachers 3 (2-2) summer
Prerequisites: Six hours of drawing, IA 205 or equivalent

A study of new developments in the field of design with emphasis on the relationship of material and form in the selection and designing of industrial arts projects. Graduate Staff

IA 560 (ED 560) New Developments in Industrial Arts Education 3 (3-0) summer
Prerequisite: Twelve hours in education and teaching experience

This course is a study of the new developments in industrial arts education. It is designed to assist teachers and administrators in developing new concepts and new content based on the changes in technology. They will be required to re-evaluate their programs in the light of these new concepts and the new content. Graduate Staff

IA 590 Laboratory Problems in Industrial Arts Maximum 6
Prerequisites: Senior standing, permission of instructor

Courses based on individual problems and designed to give advanced majors in industrial arts education the opportunity to broaden or intensify their knowledge and abilities through investigation and research in the various fields of industrial arts, such as metals, plastics, ceramics, or electricity-electronics. Graduate Staff

IA 592 Special Problems in Industrial Arts Maximum 6
Prerequisite: One term of student teaching or equivalent

The purpose of these courses is to broaden the subject matter experiences in the areas of industrial arts. Problems involving curriculum, investigation or research in one or more industrial arts areas will be required. Graduate Staff

IA 595 (ED 595) Industrial Arts Workshop 3 (3-0) summer
Prerequisite: One or more years of teaching experience

A course for experienced teachers, administrators and supervisors of industrial arts. The primary purpose will be to develop sound principles and practices for initiating, conducting and evaluating programs in this field. Enrollees will pool their knowledge and practical experiences and will do intensive research work on individual and group problems. Graduate Staff

Courses for Graduates Only

ED 630 Philosophy of Industrial Arts 2(2-0) fs
Prerequisite: Twelve hours in education
Required of all graduate students in industrial arts education.

Current and historical developments in industrial arts; philosophical concepts, functions, scope, criteria for the selection and evaluation of learning experiences, laboratory organization, student personnel program, community relationships, teacher qualifications, and problems confronting the industrial arts profession. Graduate Staff

ED 635 Administration and Supervision in Industrial Arts 2 (2-0) fs
Prerequisite: Twelve hours in education

A study of the problems and techniques of administration and supervision in the improvement of industrial arts in the public schools. Selection of teachers and their improvements in service, and methods of evaluating industrial arts programs. Mr. Young

ED 692 Seminar in Industrial Arts Education 1 (1-0) fs
Prerequisite: Graduate standing

Reviews and reports on special topics of interest to students in industrial arts education. Graduate Staff

DEPARTMENT OF INDUSTRIAL EDUCATION

GRADUATE FACULTY

Professors: DURWIN M. HANSON, *Head,* JOSEPH T. NERDEN
Associate Professor: THOMAS S. BALDWIN

The Department of Industrial Education offers graduate work leading to the degrees of Master of Science and Master of Education. The rapid development of industrial and technical education in North Carolina and throughout the nation provides many opportunities for teachers and administrators who have earned advanced degrees.

The facilities at North Carolina State University afford an excellent program of supporting courses at the graduate level in the related fields of science, mathematics, guidance, psychology, sociology, economics, statistics, and engineering. The prerequisite for graduate work in industrial education is a proficiency in the undergraduate courses required for the bachelor's degree in industrial education, or a substantial equivalent.

A limited number of teaching and research assistantships are available for qualified graduate students.

Courses for Graduates and Advanced Undergraduates

ED 516 COMMUNITY OCCUPATIONAL SURVEYS 2 (2-0) s
Prerequisites: Six credits in education, permission of instructor

Methods in organizing and conducting local surveys and evaluation of findings in planning a program of vocational education.
Messrs. Hanson, Nerden

ED 525 TRADE ANALYSIS AND COURSE CONSTRUCTION 3 (3-0) f
Prerequisites: ED 344, PSY 304

Principles and practices in analyzing occupations for the purpose of determining teaching content. Practice in the principles underlying industrial course organization based on occupational analysis covering instruction in skills and technology and including course outlines, job sequences, the development of instructional materials and schedules. Mr. Hanson

ED 527 PHILOSOPHY OF INDUSTRIAL AND TECHNICAL EDUCATION
Prerequisite: ED 422, ED 440

A presentation of the historical development of industrial and technical education; the types of programs, philosophy, trends and problems of vocational-industrial education; study of federal and state legislation pertaining to industrial education, practical nurse education, and technical education. Mr. Nerden

ED 529 CURRICULUM MATERIALS DEVELOPMENT 3 (3-0) fs
Prerequisite: ED 525

Selection and organization of curricula used in vocational-industrial and technical education; development of curricula and instructional materials. Mr. Hanson

ED 591 SPECIAL PROBLEMS IN INDUSTRIAL EDUCATION Maximum 6
Prerequisites: Six hours graduate work, permission of department head

Directed study other than thesis problem to provide individualized study and analysis in a specialized area of trade, industrial or technical education. Messrs. Hanson, Nerden

Courses for Graduates Only

ED 609 Planning and Organizing Technical Educational Programs 3 (3-0) fs
Prerequisites: PSY 304, ED 344, ED 420, ED 440, ED 516

Principles of planning and organizing technical education programs sponsored by federal vocational acts. Professional course for coordinators and directors, with emphasis on the organization of post high school technical education level. Survey of needs, building plans, equipping and maintenance of buildings, financial structure, and personnel organization and management. Messrs. Hanson, Nerden

ED 610 Administration and Supervision of Vocational Education 3 (3-0) fs
Prerequisites: PSY 304, ED 344, ED 420, ED 440 or equivalent

Administrative and supervisory problems of vocational education; practices and policies of federal and state offices; organization and administration of city and consolidated systems. Messrs. Hanson, Nerden

ED 611 Laws, Regulations and Policies Affecting Vocational Education 3 (3-0) fs
Prerequisites: ED 527, ED 610 or equivalent

A detailed study of legislation, (national and state) which applies directly to occupational education. Basic social issues and economic conditions which precipitated the legislation will be studied in depth. A review will also be made of the organizational structure and policies under which national legislation is converted into programs of occupational education. Mr. Nerden

ED 612 Finance, Accounting and Management of Vocational Education Programs 3 (3-0) fs
Prerequisites: ED 527, ED 610 or equivalent

A study of the steps which must be taken in financing a new vocational enterprise, following the determination of curriculum by area study. Costs of operation, equipment purchase procedures, costs for construction, etc. will be investigated in detail. Mr. Nerden

ED 691 Seminar in Industrial Education 1 (1-0) fs
Prerequisite: Graduate standing or permission of instructor

Reviews and reports of topics of special interest to graduate students in industrial education. The course will be offered from time to time in accordance with the availability of distinguished professors. Messrs. Hanson, Nerden

DEPARTMENT OF INDUSTRIAL ENGINEERING

GRADUATE FACULTY

Professors: Clifton A. Anderson, *Head,* Robert Gordon Carson, Jr., Jay Goldman, Robert W. Llewellyn
Associate Professors: Raul E. Alvarez, John J. Harder
Assistant Professor: John R. Canada
Adjunct Assistant Professor: John Leonard Colley, Jr.

The Department of Industrial Engineering offers graduate study leading to the Master of Science degree. The courses in the department reflect the latest technology as applied to planning, operating, and controlling manufacturing, distribution, and service enterprises.

This modern approach leads to the optimization of the effective uses of all critical resources.

Included in the program are courses in the areas of operations research, process design, system control and system design. Each individual student's course of study is specifically tailored to meet his professional needs. This educational approach allows for maximum flexibility while providing the depth of understanding so necessary in the practice of industrial engineering.

Courses for Advanced Undergraduates

IE 401 Industrial Engineering Analysis I 3 (3-0) f
Prerequisites: MA 405, IE 353

A study of linear programming methods and their applications in industrial engineering; the transportation method with applications to scheduling in transportation and production problems; the simplex method and its applications in production planning, production scheduling and allied fields; upper bound, integer, parametric and primaldual methods with their typical applications; the inter-relationships between linear programming and game theory.

IE 402 Industrial Engineering Analysis II 3 (3-0) s
Prerequisite: IE 401

An introductory study of several aspects of operations research methods with emphasis on their industrial engineering applications; replacement theory, sequencing problems, inventory control methods and dynamic programming and their applications.

IE 403 Industrial Engineering Analysis III 3 (3-0) s
Prerequisite: IE 401

An introductory study of several aspects of operations research methods with emphasis on their industrial engineering applications; continuous and discrete cybernetics with emphasis on Markov processes; finite and infinite queuing models; industrial control methods and industrial dynamics.

IE 421 Data Processing and Production Control Systems 3 (3-0) f
Prerequisites: MA 335, IE 352

This course is an introduction to the design of integrated control systems necessary for effective management of production. It will include the methods of systems design, the basic concepts of computer processing systems, the design of control procedures and reports, and their application to mechanized and electronic data processing equipment. Major emphasis will be placed on the design of control procedures for production scheduling, labor performance, and quality control. Systems flow charts, block diagrams, and program statements in compiler form will be used for each system application.

IE 453 Operations Planning and Plant Layout 3 (2-3) f
Prerequisite: IE 352

This course will provide an opportunity for the student to apply the basic principles contained in the prerequisite courses to the design of plant-wide production programs with emphasis placed on planning, arrangement, layout, and implementation of such programs. It will include operations sequencing, tooling, and equipment selection, materials handling, systems design, manpower and facilities forecasting. Suitable cases will be drawn from both mass production and jobbing operations.

Courses for Graduates and Advanced Undergraduates

IE 505 (MA 505) MATHEMATICAL PROGRAMMING I 3 (3-0) f
Prerequisite: MA 405

A study of mathematical methods applied to problems of planning. Linear programming will be covered in detail. This course is intended for those who desire to study this subject in depth and detail. It provides a rigorous and complete development of the theoretical and computational aspects of this technique as well as a discussion of a number of applications. Messrs. Alvarez, Llewellyn

IE 515 PROCESS ENGINEERING 3 (3-0) f
Prerequisites: IE 328, IE 443

The technical process of translating product design into a manufacturing program. The application of industrial engineering in the layout, tooling, methods, standards, costs, and control functions of manufacturing. Laboratory problems covering producer and consumer products. Mr. Harder

IE 517 AUTOMATIC PROCESSES 3 (3-0) s
Prerequisites: IE 328, IE 443

Principles and methods for automatic processing. The design of product, process, and controls. Economic, physical and sociological effects of automation. Mr. Harder

IE 521 CONTROL SYSTEMS AND DATA PROCESSING 3 (3-0) f
Prerequisite: IE 421

This course is designed to train the student in the problems and techniques required for systematic control of the production process and the business enterprise. This includes training in the determination of control factors, the collection and recording of data, and the processing, evaluation, and use of data. The course will illustrate the applications and use of data processing equipment and information machines in industrial processes. Case problems will be used extensively. Graduate Staff

IE 522 DYNAMICS OF INDUSTRIAL SYSTEMS 3 (3-0) s
Prerequisite: IE 421

A study of the dynamic properties of industrial systems; introduction to servomechanism theory as applied to company operations. Simulation of large nonlinear, multi-loop, stochastic systems on a digital computer; methods of determining modifications in systems design and/or operating parameters for improved system behavior. Mr. Llewellyn

IE 543 STANDARD DATA 3 (3-0) s
Prerequisite: IE 332

Theory and practice in developing standard data from stopwatch observations and predetermined time data; methods of calculating standards from data; application of standard data in cost control, production planning and scheduling, and wage incentives. Mr. Goldman

IE 546 ADVANCED QUALITY CONTROL 3 (3-0) s
Prerequisites: IE 353, ST 421

The statistical foundations of quality control are emphasized in this course as well as its economic implications. Mathematical derivations of most of the formulas used are given. Sampling techniques are treated extensively and many applications of this powerful technique are explained. Mr. Alvarez

IE 547 ENGINEERING RELIABILITY 3 (3-0) f
Prerequisites: ST 421, IE 353

The methodology of reliability including application of discrete and continuous distribution models and statistical designs; reliability estimation,

reliability structure models, reliability demonstration and decisions, and reliability growth models. Examples of reliability evaluation and demonstration programs. Mr. Colley

IE 551 STANDARD COSTS FOR MANUFACTURING 3 (3-0) s
Prerequisites: One course in accounting, one course in motion and time study

The development, application and use of standard costs as a management tool; use of industrial engineering techniques in establishing standard costs for labor, materials, and overhead. Analysis of variances and setting of budgets. Measures of management performance. Graduate Staff

IE 591 PROJECT WORK 2 to 6 fs
Prerequisite: Graduate or senior standing

Investigation and report on an assigned problem for students enrolled in the fifth-year curriculum in industrial engineering. Graduate Staff

Courses for Graduates Only

IE 607 (MA 607) SELECTED TOPICS IN MATHEMATICAL PROGRAMMING 3 (3-0) s
Prerequisite: IE 505

This course is a continuation of IE 505 (MA 505). Special techniques like the decomposition principles, network problems, diophantine programming as well as its applications to industrial problems are studied. An introduction to dynamic programming will also be covered. Multistage decision problems will be worked using linear and dynamic programming. The theoretical foundations of these techniques will be covered but emphasis will be in the applications to planning problems. Mr. Alvarez

IE 621 INVENTORY CONTROL METHODS 3 (3-0) fs
Prerequisites: IE 402, ST 421, MA 511

A study of inventory policy with respect to reorder sizes, minimum points, and production schedules. Simple inventory models with restrictions, price breaks, price changes, analysis of slow-moving inventories. Introduction to the smoothing problem in continuous manufacturing. Applications of linear and dynamic programming and zerosum game theory.
Mr. Alvarez

IE 651 SPECIAL STUDIES IN INDUSTRIAL ENGINEERING Credits by Arrangement
Prerequisite: Graduate standing

The purpose of this course is to allow individual students or small groups of students to take on studies of special areas in industrial engineering which fit into their particular program and which may not be covered by existing industrial engineering graduate level courses. The work would be directed by a qualified staff member who has particular interest in the area covered by the problem. Such problems may require individual research and initiative in the application of industrial engineering training to new areas or fields. Graduate Staff

IE 695 SEMINAR 1 (1-0) fs

Seminar discussion of industrial engineering problems for graduate students. Case analyses and reports. Mr. Llewellyn

IE 699 INDUSTRIAL ENGINEERING RESEARCH Credits by Arrangement

Graduate research in industrial engineering for thesis credit.
Graduate Staff

DEPARTMENT OF MATHEMATICS

GRADUATE FACULTY

Professors: JOHN WESLEY CELL, *Head*, ROBERTS COZART BULLOCK, JOHN MONTGOMERY CLARKSON, WALTER JOEL HARRINGTON, JACK LEVINE, PAUL EDWIN LEWIS, *Director of Computing Center*, CAREY GARDNER MUMFORD, HOWARD MOVESS NAHIKIAN, *Graduate Administrator*, HUBERT VERN PARK, HANS SAGAN, HERBERT ELVIN SPEECE, RAIMOND ALDRICH STRUBLE, HUBERTUS ROBERT VAN DER VAART, JOHN PASCAL VINTI, OSCAR WESLER, LOWELL SHERIDAN WINTON

Visiting Professor: MAKOTO ITOH

Adjunct Professors: ALAN STUART GALBRAITH, LEONARD ROBERTS, IAN NAISMITH SNEDDON

Associate Professors: JOHN WILLIAM BISHIR, PAUL ADRIAN NICKEL, JOHN WILLIAM QUERRY, TSUAN WU TING

Visiting Associate Professor: ANDREW NISBET

Adjunct Associate Professor: ROBERT TAYLOR HERBST

Assistant Professors: RICHARD EDWARD CHANDLER, DONALD JOSEPH HANSEN, KWANGIL KOH, JOSEPH DAVID ZUND

Visiting Assistant Professor: ERNEST EDMUND BURNISTON

Instructor: JOE ALTON MARLIN

The Department of Mathematics offers graduate studies in applied mathematics leading to the Master of Applied Mathematics, the Master of Science, and the Doctor of Philosophy degrees. The Master of Applied Mathematics degree does not require a thesis or a foreign language, but in all other respects it is the same as the Master of Science degree. Students who are admitted to the Graduate School to pursue studies in applied mathematics are expected to have had a strong undergraduate major in mathematics, including a year of advanced calculus and a year of modern algebra including abstract algebra and matrices. Those students who do not have these courses will be required to take them in addition to the minimum number required for the master's degree. The areas of application require that the student offer a minor in some mathematically oriented area such as physics, the engineering sciences, genetics, or statistics.

Individuals with graduate training in applied mathematics are in great demand in industry, governmental laboratories, and college teaching positions. Opportunities are many and varied in this field and include work as a member of a research team in such areas as satellite orbit theory, viscoelasticity, biomathematics, thermodynamics, aerodynamics, acoustics, solid state physics, nuclear reactor theory, geophysics, and in applications of computers in business.

The department has available a number of teaching and research assistantships (a student holding a half-time assistantship is allowed to carry a study load of nine semester hours). Also available for those graduate students studying toward the doctoral degree are a limited number of NSF, NASA, and Ford Foundation Fellowships.

Courses for Advanced Undergraduates

MA 401 Topics from Advanced Calculus I 3 (3-0) fs
Prerequisite: MA 301

Infinite series and integrals; linear differential equations; special functions.

MA 402 Topics from Advanced Calculus II 3 (3-0) fs
Prerequisite: MA 401

Partial differentiation, functional dependence, Jacobians, maxima and minima, differentiation of definite integrals involving a parameter, vector analysis, orthogonal functions including Fourier series and Fourier integral, Fourier-Bessel series, and Fourier-Legendre series.

MA 403 Fundamental Concepts of Algebra 3 (3-0) fs
Prerequisite: MA 202 or MA 212

Integers; integral domains; rational numbers; fields, rings, groups, Boolean algebra.

MA 404 Fundamental Concepts of Geometry 3 (3-0) s
Prerequisite: MA 202 or MA 212

Foundations of geometry; laws of logic; affine geometry; geometric transformations; homogeneous coordinates; comparison of Euclidean and non-Euclidean geometries.

MA 405 Introduction to Determinants and Matrices 3 (3-0) fs
Prerequisite: MA 202 or MA 212

Properties of determinants; theorems of Laplace and Jacobi; systems of linear equations. Elementary operations with matrices; inverse, rank, characteristic roots and eigenvectors. Introduction to algebraic forms.

MA 408 Advanced Geometry 3 (3-0) f
Prerequisite: MA 202 or MA 212

Topics from modern geometry; poles and polars; non-Euclidean geometry; analytical geometry from a vector point of view; elementary geometry from an advanced standpoint.

MA 421 Introduction to Probability 3 (3-0) fs
Prerequisite: MA 301 or permission of department

Definitions, discrete and continuous sample spaces, combinatorial analysis, Stirling's formula, simple occupancy and ordering problems, conditional probability, repeated trials, compound experiments, Bayes' theorem, binomial, Poisson and normal distribution, the probability integral, random variables, expectation.

MA 433 History of Mathematics 3 (3-0) s
Prerequisite: MA 202 or MA 212

Evolution of the number system; trends in the development of modern mathematics; lives and contributions of outstanding mathematicians.

MA 451 Numerical Analysis Laboratory I 1 (0-3) f
Prerequisites: MA 337, MA 351 or permission of instructor
Corequisite: MA 527

Programming for digital computers involving subroutines and selected topics in numerical analysis.

MA 452 Numerical Analysis Laboratory II 1 (0-3) s
Prerequisite: MA 541 or permission of instructor
Corequisite: MA 528

Programming for digital computers involving selected topics in numerical analysis.

MA 481 Special Topics 1 to 6 fs
Prerequisite: Permission of department

MA 491 Reading in Honors Mathematics 2 to 6 fs
Prerequisites: Membership in honors program, permission of department head

Courses for Graduates and Advanced Undergraduates

MA 505 See IE 505, Mathematical Programming I. 3 (3-0) f

MA 511 Advanced Calculus I 3 (3-0) fs
Prerequisites: MA 301 and, preferably, a B-average in all mathematics courses

Vectors, differential calculus of functions of several variables, vector differential calculus. Definite integral. Graduate Staff

MA 512 Advanced Calculus II 3 (3-0) fs
Prerequisite: MA 511

Vector integral calculus, infinite series, integral calculus of functions of several variables. Graduate Staff

MA 513 Introduction to Complex Variables 3 (3-0) fs
Prerequisite: MA 512 or equivalent

Operations with complex numbers, derivatives, analytic functions, integrals, definitions and properties of elementary functions, multi-valued functions, power series, residue theory and applications, conformal mapping. Graduate Staff

MA 514 Methods of Applied Mathematics 3 (3-0) s
Prerequisite: MA 512 or equivalent

Introduction to difference equations, integral equations, and the calculus of variations. Graduate Staff

MA 516 Principles of Mathematical Analysis 3 (3-0) f
Prerequisite: MA 512

The real number system, elements of set theory, limits, continuity, differentiation, Reimann-Stieltjes integration, sequences of functions, fundamentals of Lebesque theory, topological and metric spaces. Mr. Struble

MA 517 Introduction to Point-Set Topology 3 (3-0) s
Prerequisite: MA 516

A study of basic set-theoretic and general topological notions of modern mathematics. Topics include set theory and cardinal numbers, topological spaces, metric spaces, and elementary discussion of function spaces. Mr. Chandler

MA 521 A Survey of Modern Algebra 3 (3-0) f
Prerequisite: MA 403 or permission of instructor

Properties of the integers, mappings, abstract groups, and other algebraic structures with emphasis upon applications and proofs. Mr. Koh

MA 524 Boundary Value Problems 3 (3-0) fs
Prerequisite: MA 402 or MA 511

Theory of first variation with applications to various physical phenomena (vibrating string, vibrating membrane, heat conduction, and wave propagation); Bernoulli's separation theorem with application to vibration and heat conduction problems; Fourier series, Fourier-Bessel series, and Fourier-Legendre series and a full discussion of the Sturm-Liouville problem; numerical approximation of eigenvalues by Rayleigh-Ritz method. Messrs. Burniston, Sagan

MA 527 Numerical Analysis I 3 (3-0) fs
Prerequisite: MA 402 or MA 511

Numerical solution of equations, introduction to the theory of errors, finite-differences tables and the theory of interpolation, numerical integration, numerical differentiation, and elements of difference calculus. Graduate Staff

MA 528 Numerical Analysis II 3 (3-0) s
Prerequisite: MA 527

Difference operators, summation procedures, numerical solution of ordinary differential equations, least-squares polynominal approximations, and Gaussian quadrature. Graduate Staff

MA 532 Theory of Ordinary Differential Equations 3 (3-0) s
Prerequisite: MA 511

First order equations, linear n^{th} order equations with constant coefficients and with continuous coefficients, Green's functions, solution on linear equations with analytic coefficients, second order linear equations with regular singular points, systems of first order equations, uniqueness theorems, existence theorems of Picard and Peano, stability of solutions of linear plane autonomous systems, numerical solutions. Mr. Sagan

MA 536 Logic for Digital Computers 3 (3-0) f
Prerequisite: MA 405

Introduction to symbolic logic and Boolean algebra; finite state-valued calculus and its application to combinational networks; sequential finite-state machines and their mathematical formulation; analysis and synthesis problems of sequential machines. Mr. Itoh

MA 537 Mathematical Theory of Digital Computers 3 (3-0) s
Prerequisite: MA 536

The sequential machine and its characteristic semi-group; micro-programmed computers; general purpose computers and special-purpose computers; Turing machine and infinite-state machines; non-deterministic switching system and probabilistic automata. Mr. Itoh

MA 541 (ST 541) Theory of Probability I 3 (3-0) f
Prerequisite: MA 511

Axioms, discrete and continuous sample spaces, events, combinatorial analysis, conditional probability, repeated trials, independence, random variables, expectation, special discrete and continuous distributions, probability and moment generating functions, central limit theorem, laws of large numbers, branching processes, recurrent events, random walk. Mr. Bishir

MA 542 (ST 542) Theory of Probability II 3 (3-0) s
Prerequisites: MA 405, MA 541

Markov chains and Markov processes, Poisson process, birth and death processes, queueing theory, renewal theory, stationary processes, Brownian motion, information theory. Mr. Bishir

MA 555 (PY 555) Principles of Astrodynamics 3 (3-0) s
Prerequisites: MA 511, PY 411 or EM 312

The differential equations of motion in two-body problems and their integrals; orbit theory; integrals of the n-body problem; differential equations of motion of natural and artificial satellites and their approximate solutions. Mr. Vinti

MA 571 See ST 571, Biomathematics I. 3 (3-0) f

MA 572 See ST 572, Biomathematics II. 3 (3-0) s

MA 581 Special Topics 1 to 6
Prerequisite: Permission of department Graduate Staff

Courses for Graduates Only

MA 602 Partial Differential Equations I 3 (3-0) f
Prerequisite: Graduate standing in mathematics or permission of instructor

Equations in two independent variables: First order equations, boundary

value problems for the principal second order types, theory of characteristics. Existence and uniqueness by majorant series and by successive approximations. Maximum principle. Approximation methods.
Messrs. Struble, Ting

MA 603 PARTIAL DIFFERENTIAL EQUATIONS II 3 (3-0) s
Prerequisite: MA 602

Continuation of MA 602. Equations in many independent variables: Relationships with the calculus of variations, generalizations of the concept of a solution and unifying concepts, applications.
Messrs. Struble, Ting

MA 605 NON-LINEAR DIFFERENTIAL EQUATIONS 3 (3-0) f
Prerequisites: MA 512, MA 532

Phase-plane and phase-space concepts; existence and uniqueness theorems; continuity, analytic and differentiability properties of solution; properties of linear systems; stability in non-linear systems; topological methods; perturbations of periodic solutions; asymptotic methods and resonance problems. Mr. Struble

MA 606 See ST 606, MATHEMATICAL PROGRAMMING II. 3 (3-0) fs

MA 607 See IE 607, SPECIAL TOPICS IN MATHEMATICAL PROGRAMMING. 3 (3-0) fs

MA 608 INTEGRAL EQUATIONS 3 (3-0) alternate summers
Prerequisites: MA 512, MA 532

Linear Volterra integral equations of the first and second kinds. Relationship to linear differential initial value problems. Special Volterra equations of the convolution type. Singular Volterra equations. Linear Fredholm integral equations of the first and second kind. Basic theory. Symmetric kernels. Hilbert-Schmidt theory (generalizations).
Mr. Winton

MA 611 COMPLEX VARIABLE THEORY AND APPLICATIONS I 3 (3-0) f
Prerequisite: MA 512

Elementary functions; analytic functions and Cauchy-Riemann equations; conformal mapping and applications; Taylor and Laurent series; contour integration and residue theory; the Schwarz-Christoffel transformation.
Messrs. Bullock, Nickel, Sagan

MA 612 COMPLEX VARIABLE THEORY AND APPLICATIONS II 3 (3-0) s
Prerequisite: MA 611

Conformal mapping and applications to flow phenomena; multiple-valued functions and Riemann surfaces; further applications of residue theory; analytic continuation; infinite series and asymptotic expansions; elliptic functions and other special functions in the complex domain; representation theorems. Messrs. Bullock, Nickel, Sagan

MA 615 THEORY OF FUNCTIONS OF A REAL VARIABLE I 3 (3-0) f
Prerequisites: MA 516, MA 517, or equivalent

Lebesgue measure on the real line and the Lebesgue integral; differentiation of monotone functions and of integrals; absolute continuity; topological, metric and L^p spaces. Mr. Harrington

MA 616 THEORY OF FUNCTIONS OF A REAL VARIABLE II 3 (3-0) s
Prerequisite: MA 615

General measure and integration theory in terms of measure spaces and measurable functions; the Lebesgue-Stielges integral; Banach spaces and linear functionals. Mr. Harrington

MA 617 See ST 617, MEASURE THEORY AND ADVANCED PROBABILITY. 3 (3-0) f

MA 618 See ST 618, Measure Theory and Advanced Probability. 3 (3-0) s

MA 619 See ST 619, Topics in Advanced Probability. 3 (3-0) f

MA 621 Introduction to Modern Abstract Algebra 3 (3-0) s
Prerequisite: MA 403 or equivalent

A study of the abstract structure and properties of groups, rings and ideals, and fields. Messrs. Koh, Nahikian, Park

MA 622 Linear Algebra 3 (3-0) f
Prerequisite: MA 405 or equivalent

A study of vector spaces and their relation to the theory of matrices, the characteristic and minimal polynomials of a matrix, functions of matrices, theory of elementary divisors, canonical forms of a matrix, application to systems of differential equations. Messrs. Nahikian, Park

MA 625 Introduction to Differential Geometry 3 (3-0) alternate summers
Prerequisite: MA 512

Theory of curves and surfaces in 3-dimensional Euclidean space with special reference to those properties invariant under rigid body motions. Messrs. Levine, Zund

MA 632 Operational Mathematics I 3 (3-0) f
Corequisite: MA 513 or MA 611

Laplace transform with theory and application to ordinary and partial differential equations arising from problems in engineering and physics. Messrs. Cell, Harrington

MA 633 Operational Mathematics II 3 (3-0) s
Prerequisite: MA 632

Extended development of the Laplace and Fourier transforms and their application to the solution of ordinary and partial differential equations, integral equations, and difference equations; Z-transforms, other infinite and finite transforms and their applications. Messrs. Cell, Harrington

MA 635 Numerical Analysis III 3 (3-0) s
Prerequisites: MA 335, MA 512, MA 528
Corequisite: MA 405 or MA 622

The development of methods for the solution of selected problems involving matrices, integral rational equations, ordinary and partial differential equations. Particular attention is paid to the question of convergence and stability. Examples are solved on the IBM 360 system. Graduate Staff

MA 641 Calculus of Variations 3 (3-0) f
Prerequisite: MA 512

The integrals in the calculus of variations as differentiable functionals, first and second variation as first and second differential of a functional, first necessary condition for an extremum of a simple and double integral as a functional of one or n functions with fixed and variable terminal-manifolds, broken extremals, the theory of Hamilton and Jacobi, the problem of Mayer, Legendre and Jacobi condition, field theory, Hilbert's invariant integral and Weierstrass' Excess function, minimizing sequences and the method of Rayleigh-Ritz as applied to quadratic functionals. Mr. Sagan

MA 647 Functional Analysis I 3 (3-0) f
Prerequisites: MA 615, MA 616

Complete, separable, and compact metric spaces, completeness of L_p,

Hilbert spaces, Riesz-Fischer Theorem, linear operators on normed, linear spaces. Mr. Sagan

MA 648 FUNCTIONAL ANALYSIS II 3 (3-0) s
Prerequisite: MA 647

Linear functionals on normed linear spaces, Hahn-Banach Theorem, representation of linear functionals, completely continuous operators, self adjoint operators on a Hilbert space, inverse operators, spectral representation of self adjoint operators, approximate solution of linear operator equations. Mr. Sagan

MA 651 EXPANSION OF FUNCTIONS 3 (3-0) alternate summers
Prerequisites: MA 611, MA 633, or equivalent

Expansion of functions of one or more variables in Taylor's series; asymptotic series; infinite products, partial fractions, continued fractions, series of orthogonal functions; applications to ordinary and partial differential equations, difference equations, and integral equations.
Messrs. Cell, Harrington

MA 655 MATHEMATICS OF ASTRODYNAMICS I 3 (3-0) f
Prerequisite: MA 532 or MA 605

Lagrangian and Hamiltonian dynamics, Hamilton-Jacobi equation, two-body problem, canonical transformations, Delaunay variables, deduction of the method of variation of parameters from the canonical theory, theory of the gravitational potential, perturbation theories of Kazai and Brouwer-von Zeipel for orbits of artificial satellites. Mr. Vinti

MA 656 MATHEMATICS OF ASTRODYNAMICS II 3 (3-0) s
Prerequisite: MA 655

Theory of separable systems, including the spheroidal method for artificial satellites, the general and restricted three-body problems, Lagrange points and librational motion, lunar and planetary disturbing functions, lunar and planetary theories. Mr. Vinti

MA 661 TENSOR ANALYSIS I 3 (3-0) f
Prerequisite: MA 512

The basic theory of tensor algebra and tensor calculus. Riemannian spaces and generalizations. Messrs. Levine, Zund

MA 662 TENSOR ANALYSIS II 3 (3-0) s
Prerequisite: MA 661

The application of tensor analysis to selected topics in applied mathematics and physical sciences; typically, differential geometry, elasticity, electromagnetic theory, classical mechanics, and general relativity.
Messrs. Levine, Zund

MA 681 SPECIAL TOPICS IN ANALYSIS 1-6 credits

MA 683 SPECIAL TOPICS IN ALGEBRA 1-6 credits

MA 685 SPECIAL TOPICS IN NUMERICAL ANALYSIS 1-6 credits

MA 687 SPECIAL TOPICS IN GEOMETRY 1-6 credits

MA 689 SPECIAL TOPICS IN APPLIED MATHEMATICS 1-6 credits

The above courses, MA 681-MA 689, afford opportunities for graduate students to study advanced topics in mathematics under the direction of members of the graduate staff. These will on occasion consist of one of several areas such as, for example, advanced theory of partial differential equations, topology, mathematics of elasticity or of viscoelasticity, orbital mechanics, functional analysis, combinatoral analysis. Graduate Staff

MA 699 RESEARCH IN MATHEMATICS Credits by Arrangement
Prerequisites: Graduate standing, permission of advisor

Individual research in the field of mathematics. Graduate Staff

DEPARTMENT OF MATHEMATICS AND SCIENCE EDUCATION

GRADUATE FACULTY

Professor: HERBERT E. SPEECE, *Head*
Assistant Professor: NORMAN D. ANDERSON

The Department of Mathematics and Science Education offers graduate work leading to the degrees of Master of Science and Master of Education, with a major in mathematics education or science education. Each student's program is individually planned by a graduate committee and will reflect his undergraduate preparation, teaching experience, and future professional plans. Areas of specialization include mathematics, biological science, earth science, chemistry and physics. A minimum of thirty-six semester hours is required, of which sixty percent must be in the area of subject matter specialization and twenty percent in professional education. Candidates for the Master of Education degrees are required to submit a scholarly research paper; candidates for the Master of Science degree must conduct an investigation culminating in a thesis. The Master of Science degree also requires a reading knowledge of one foreign language.

Applicants must meet the admissions requirements of the Graduate School of North Carolina State University. Applicants must also have the approval of the Department of Mathematics and Science Education. To be admitted to the program without subject matter deficiencies, applicants must have completed a degree in which they have reached a level of undergraduate work closely approximating the following minimum: two years of English, one year of physics, one year of chemistry, one and one-half years in the historical-philosophical and psychology foundations of education. In addition to the above, those specializing in mathematics should have had three years of mathematics; those specializing in science should have had one year of biology, one and preferably two years of mathematics, and two years of advanced work in one of the sciences.

A limited number of assistantships are available. For those desiring financial assistance, inquiries should be directed to the Department of Mathematics and Science Education.

Courses for Graduates and Advanced Undergraduates

ED 592 SPECIAL PROBLEMS IN MATHEMATICS TEACHING **3 (0-3) fs**
Prerequisite: ED 471 or equivalent

An investigation of current problems in mathematics teaching, with emphasis on the areas of curriculum, methodology, facilities, supervision and research. Specific problems will be studied in depth. Opportunities will be provided to initiate research studies. Mr. Speece

ED 594 SPECIAL PROBLEMS IN SCIENCE TEACHING **3 (0-3) fs**
Prerequisite: ED 476 or equivalent

An investigation of current problems in science teaching with emphasis on the areas of curriculum, methodology, facilities, supervision and

research. Specific problems will be studied in depth. Opportunities will be provided to initiate research studies. Graduate Staff

Courses for Graduates Only

ED 690 SEMINAR IN MATHEMATICS EDUCATION Maximum 2 fs
Prerequisites: Graduate standing, permission of instructor

A critical analysis of issues, trends and recent developments in mathematics education. Mr. Speece

ED 695 SEMINAR IN SCIENCE EDUCATION Maximum 2 fs
Prerequisites: Graduate standing, permission of instructor

A critical analysis of issues, trends, and recent developments in science education. Graduate Staff

DEPARTMENT OF MECHANICAL ENGINEERING

GRADUATE FACULTY

Professors: ROBERT WESLEY TRUITT, *Head,* NORVAL WHITE CONNER, JESSE SEYMOUR DOOLITTLE, *Graduate Administrator,* MUNIR R. EL-SADEN, KARL P. HANSON, HASSAN A. HASSAN, RICHARD BENNETT KNIGHT, ROBERT MCLEAN PINKERTON, FREDERICK O. SMETANA, JAMES CLIFFORD WILLIAMS, III, JAMES WOODBURN, CARL FRANK ZOROWSKI

Associate Professors: BERTRAM HOWARD GARCIA, FRANCIS JOSEPH HALE, M. NECATI OZISIK, JOHN NOBLE PERKINS, JOHN KERR WHITFIELD

Assistant Professors: ROLIN FARRAR BARRETT, FRANKLIN DELANO HART, THOMAS BENSON LEDBETTER, HUSEYIN CAVIT TOPAKOGLU

The Department of Mechanical Engineering offers graduate study leading to the Master of Science and Doctor of Philosophy degrees. Entrance to the various programs in the department is normally based upon an accredited baccalaureate degree in engineering.

At present the major emphases in graduate study are the thermal sciences, including classical thermodynamics, heat transfer and transport phenomena, statistical thermodynamics, and direct energy conversion; gas dynamics (aerothermochemistry, aerothermodynamics, plasmagasdynamics, magnetogasdynamics and rarefied gasdynamics), and the mechanical sciences, such as principles of fluid motion, dynamics of compressible flow and viscous fluids, vibrations, mechanical transients and stress analysis; the aerospace sciences of aerodynamics, propulsion, boundary layer theory and heat transfer, and spacecraft design.

The professional technological interests of the department are represented by graduate courses in nuclear power plants, steam and gas turbines, refrigeration, internal combustion engines, lubrication, mechanics of machinery, and machine design analysis and synthesis.

Graduate programs in mechanical engineering normally include substantial work in the basic sciences of mathematics and physics, and study in related engineering departments is encouraged.

The fundamental objective of graduate study in this field is to prepare the student for leadership in the various areas of research, teaching, and design. The graduate student is placed in close association

with the graduate faculty who conduct individual research. Participation in a research project as a research assistant or employment as a teaching assistant is regarded as significant experience during residence.

Courses for Advanced Undergraduates

ME 401 Energy Conversion 3 (3-0) fs
Prerequisite: ME 302

A course on the conversion of energy for engineering purposes based upon the fundamentals leading to engineering decisions in the arrangement and selection of energy conversion equipment. The conventional type of plant for energy conversion and the unconventional types, in particular, direct energy conversion and the feasibility of such plants. Factors which effect the cost of power and elements entering into the problem of monetary rates.

ME 402 Heat and Mass Transfer 3 (3-0) fs
Prerequisites: ME 302, MA 301

A study of the fundamental relationships of steady and transient heat transfer of conduction, convection, radiation and during changes of phase; mass transfer by diffusion and convection; simultaneous mass and heat transfer.

ME 403 Air Conditioning 3 (3-0) f
Prerequisite: ME 302

A fundamental study of summer and winter air conditioning including temperature, humidity, air velocity and distribution. Mr. Knight

ME 404 Refrigeration 3 (3-0) s
Prerequisite: ME 302

A thermodynamic analysis of the simple, compound, centrifugal and multiple effect compression systems, the steam jet system and the absorption system of refrigeration. Mr. Knight

ME 405 Mechanical Engineering Laboratory III 1 (0-3) f
Prerequisite: ME 306
Required of seniors in mechanical engineering.

The selection of appropriate instrumentation and the experimental analysis of small, predetermined engineering systems designed for flexibility and wide variation of parameters. Systems cover the gamut of mechanical engineering activity with emphasis on analysis of system rather than characteristics of particular systems.

ME 406 Mechanical Engineering Laboratory IV 1 (0-3) s
Prerequisite: ME 405

Individual or small group investigation of an original problem under the supervision of a faculty member with an interest in the problem area. The investigation may be experimental, analytical, or both. Emphasis is placed on the philosophy and methodology of engineering research, and on individual thinking and effort.

ME 410 Jet Propulsion 3 (3-0) s
Prerequisites: ME 302, ME 352 or EM 303

Application of fundamental principles of thermodynamics and the mechanics of a compressible fluid to the processes of jet-propulsion and turbo-propeller aircraft; the effect of performance of components on performance of engine; analysis of engine performance parameters.

ME 411, 412 Mechanical Design I, II 3 (3-0) fs
Prerequisites: EM 301, MIM 201, ME 315

Application of the engineering and material sciences to the analysis

and design of mechanical components and systems. Consideration and utilization of the design process including problem definition, solution synthesis, design analysis, optimization, and prototype evaluation through design project activity.

ME 421 Aerospace Propulsion Systems 3 (3-0) f
Prerequisite: ME 353
Corequisite: ME 461

A study of propulsion systems and their relation to the various flight regimes and space missions. The principles of thrust generation, the control, and the performance of various propulsion systems will be considered.

ME 422 Direct Energy Conversion Devices 3 (3-0) fs
Prerequisites: ME 353; EE 202 or EE 332

Theory and application of direct energy conversion devices, thermoelectric and thermionic converters, solar and fuel cells, magnetohydrodynamic power generators, thermodynamic analysis, device characteristics and design considerations.

ME 431 Thermodynamics of Fluid Flow 3 (3-0) fs
Prerequisites: MA 301; EM 303 or ME 352; ME 302

The fundamental dynamics and thermodynamic principles governing the flow of gases are presented from both theoretical and experimental viewpoints. Mathematical relations are closely correlated with physical phenomena to emphasize the complimentary nature of theory and experiment.

ME 432 Boundary Layer Theory and Heat Transfer 3 (3-0) fs
Prerequisites: C or better in ME 352; MA 401 or MA 511

The course is intended to give the student both a physical and mathematical understanding of the problems of skin friction and heat transfer in present-day aerospace engineering.

ME 435 Industrial Automatic Controls 3 (3-0) fs
Prerequisites: ME 301, MA 301

Introduction to concept of automatic controls; fundamentals of two-position, proportional, floating and rate modes of control with a graphical and analytical representation of each. Theoretical considerations of the process and an introduction to system analysis.

ME 447 Performance, Stability and Control of Flight Vehicles 3 (3-0) f
Prerequisites: C or better in ME 352; MA 401 or MA 511

A study of aerodynamic and inertial factors and how they influence the motion of flight vehicles and their performance. The transfer function approach is emphasized in the analysis of flight vehicle motion.

ME 450 Introduction to Vacuum Technology 3 (2-3) fs
Prerequisite: ME 301

An introduction to the physical phenomena and apparatus associated with vacuum technology and rarefied gas research. Instruction in the use of vacuum laboratory equipment and demonstration of basic rarefied gas phenomena will be emphasized.

ME 461 Aerospace Technology 3 (3-0) s
Prerequisite: ME 353

An introduction to the principles of flight in and beyond the atmosphere. Includes the elements of aerodynamics of flight, the reentry problem, flight dynamics, guidance and control, power generation in space, manned and unmanned space flight and life support systems.

ME 465, 466 Aerospace Engineering Laboratory 1 (0-3) fs
Prerequisites: ME 306, ME 352

Laboratory experience in wind tunnel experimentation, structural testing, environmental testing, and instrumentation for flight in and beyond the atmosphere.

ME 468 Spacecraft Structures 3 (3-0) f
Prerequisite: ME 369
Corequisite: ME 461

Basic techniques and procedures in the analysis of stresses and strains caused by the extreme heating of reentry space vehicles as well as the dynamic and impulsive loads occurring during the launching and loading period of flight will be considered and the resulting effects on the vehicle structure will be studied.

ME 481 Flight Vehicle Design 5 (3-6) s
Prerequisites: ME 353, ME 461, ME 468, ME 447, ME 421, EE 202

Integration of previous aerodynamic, heat transfer, materials, structures, and dynamical theory in the design of typical air-supported and space vehicles and their sub-systems.

ME 495 Technical Seminar 1 (1-0) fs
Prerequisite: Graduating senior standing

Meetings once a week for the delivery and discussion of student papers on topics of current interest in mechanical engineering.

Courses for Graduates and Advanced Undergraduates

ME 501 Steam and Gas Turbines 3 (3-0) fs
Prerequisites: ME 302, EM 303 or ME 352

Fundamental analysis of the theory and design of turbomachinery flow passages; control and performance of turbomachinery; gas-turbine engine processes. Mr. Doolittle

ME 507, 508 Internal Combustion Engine Fundamentals 3 (3-0) fs
Prerequisite: ME 302

The fundamentals common to internal combustion engine cycles of operation. The Otto engine: carburetion, fuel distribution, flame propagation, normal and knocking combustion, throttling, pumping, valve and spark timing, and altitude effects; the Diesel engine: injection and spray formation fuel rating, automization, penetration, diesel knock, combustion, pre-combustion, and scavenging as applied to reciprocating and rotary engines. Mr. Ledbetter

ME 515 Experimental Stress Analysis 3 (2-3) f
Prerequisite: ME 315

Theoretical and experimental techniques of strain and stress analysis with emphasis on electrical strain gages and instrumentation, brittle coatings, grid methods, and an introduction to photoelasticity. Laboratory includes an investigation and complete report of a problem chosen by the student under the guidance of the instructor. Mr. Whitfield

ME 516 Photoelasticity 3 (2-3) s
Prerequisite: ME 411

Theory and experimental techniques of two and three dimensional photoelasticity including photoelastic coatings, photoplasticity, and application of photoelastic methods to the solution of mechanical design problems. Laboratory includes an investigation and complete report of a problem chosen by the student under the guidance of the instructor.
Mr. Whitfield

ME 517 Lubrication 2 (2-3) s
Prerequisite: EM 303

The theory of hydrodynamic lubrication; Reynold's equation, the Sommer-

field integration, effect of variable lubricant properties and energy equation for temperature rise. Properties of lubricants. Application to design of bearings. Boundary lubrication. Mr. Barrett

ME 521 AEROTHERMODYNAMICS 3 (3-0) f or s
Prerequisites: ME 301; ME 352 or EM 303

Review of basic thermodynamics pertinent to gasdynamics. Detailed development of the general equations governing gas motion in both differential and integral form. Simplification of the equations to those for specialized flow regimes. Similarity parameters. Applications to simpler problems in various flow regimes. Mr. Perkins

ME 531 PLASMAGASDYNAMICS I 3 (3-0) fs
Prerequisites: PY 414, ME 353

Study of basic laws governing plasma motion for dense and rarefied plasmas, hydromagnetic shocks, plasma waves and instabilities, simple engineering applications. Mr. Hassan

ME 541, 542 AERODYNAMIC HEATING 3 (3-0) fs
Prerequisites: MA 511, ME 521

A detailed study of the lastest theoretical and experimental findings of the compressible laminar and turbulent boundary layers with special attention to the aerodynamic heating problem; application of theory in the analysis and design of aerospace hardware. Mr. Williams

ME 545, 546 PROJECT WORK IN MECHANICAL ENGINEERING I, II 2 (0-4) fs

Individual or small group investigation of a problem stemming from a mutual student-faculty interest. Emphasis is placed on providing a situation for exploiting student curiosity. Graduate Staff

ME 554 ADVANCED AERODYNAMIC THEORY 3 (3-0) s
Prerequisite: ME 352

Development of fundamental aerodynamic theory. Emphasis upon mathematical analysis and derivation of equations of motion, airfoil theory and comparison with experimental results. Introduction to supersonic flow theory. Mr. Pinkerton

ME 562 ADVANCED AIRCRAFT STRUCTURES 3 (3-0) s
Prerequisite: ME 468

Development of methods of stress analysis for aircraft structures, special problems in structural design, stiffened panels, rigid frames, indeterminate structures, general relaxation theory. Mr. Topakoglu

ME 581, 582 HYPERSONIC AERODYNAMICS 3 (3-0) fs
Prerequisites: MA 512, ME 521

A detailed study of the latest theoretical and experimental findings in hypersonic aerodynamics. Mr. Truitt

ME 593 SPECIAL TOPICS IN MECHANICAL ENGINEERING 3 (3-0) f or s

Faculty and student discussions of special topics in mechanical engineering. Graduate Staff

ME 601 ADVANCED ENGINEERING THERMODYNAMICS 3 (3-0) f
Prerequisites: ME 302; MA 401 or MA 511

Thermodynamics of a general reactive system; conservation of energy and the principle of increase of entropy; the fundamental relation of thermodynamics; Legendre transformations; equilibrium and stability criteria in different representations; general relations; chemical thermodynamics; multireaction systems; ionization; irreversible thermodynamics; the Onsager relation; applications to thermoelectric, thermomagnetic and diffusional processes. Mr. El-Saden

ME 602 STATISTICAL THERMODYNAMICS 3 (3-0) s
Prerequisite: ME 601

Fundamental principles of kinetic theory, quantum mechanics, statistical mechanics and irreversible phenomena with particular reference to thermodynamics systems and processes. The conclusions of the classical thermodynamics are analyzed and established from the microscopic viewpoint. Mr. El-Saden

ME 603 Advanced Power Plants 3 (3-0) f
Prerequisite: ME 401

A critical analysis of the energy balance of thermal power plants, thermodynamics and economic evaluation of alternate schemes of development; study of recent developments in the production of power.
Mr. Doolittle

ME 605 Aerothermochemistry 3 (3-0) s
Prerequisites: ME 601, MA 511

A generalized treatment of combustion thermodynamics including derivation of thermodynamic quantities by the method of Jacobians, criteria for thermodynamic equilibrium, computation of equilibrium composition and adiabatic flame temperature. Introduction to classical chemical kinetics. Conservation equations for a reacting system, detonation and deflagration. Theories of flame propagation, flame stabilization, and turbulent combustion. Mr. Perkins

ME 606 Advanced Gas Dynamics 3 (3-0) s
Prerequisites: ME 521, ME 601, MA 511

The general conservation equations of gas dynamics from a differential and integral point of view. Hyperbolic compressible flow equations, unsteady one-dimensional flows, the non-linear problem of shock wave formation, isentropic flow, flow in nozzles and jets, turbulent flow.
Mr. Smetana

ME 608 Advanced Heat Transfer I 3 (3-0) f
Prerequisite: ME 402

Fundamental aspects, from an advanced viewpoint, will be considered in the conduction of heat through solids, convective phenomena, and the measurement and prediction of appropriate physical properties. Boundary value problems arising in heat conduction will be examined and both numerical and function solution techniques developed. Internal and external boundary layer analyses will be made on a variety of representative convection situations. Mr. Ozisik

ME 609 Advanced Heat Transfer II 3 (3-0) s
Prerequisite: ME 608

Advanced topics in the non-isothermal flow of fluids through channels will be investigated for slug, laminar, transitional and turbulent conditions. The influence of mass transfer on flow and heat transfer processes will be considered. Radiation exchange processes between solid surfaces, and solid surfaces and gases both stationary and moving will be discussed.
Mr. Ozisik

ME 610 Advanced Topics in Heat Transfer 3 (3-0) f
Prerequisite: ME 609

This course constitutes a study of recent developments in heat transfer and related areas. It is anticipated that the course content will change from semester to semester. Mr. Ozisik

ME 611, 612 Advanced Machine Design I, II 3 (3-0) fs
Prerequisite: ME 412

An advanced integrated treatment of stress analysis and materials engineering devoted to current rational methods of analysis and design applicable to mechanical components. Primary attention placed on the determination and prediction of strength, life, and deformation characteristics of machine components as dictated by performance requirements.
Messrs. Garcia, Zorowski

ME 613 Mechanics of Machinery 3 (3-0) f
Prerequisites: ME 315; MA 512 or MA 402

Advanced applications of dynamics to the design and response analysis of dynamic behavior of machines and mechanical devices. Emphasis on developing competence in transforming real problems in dynamics into appropriate mathematical models whose analysis permits performance predictions of engineering value. Messrs. Hart, Whitfield

ME 614 Mechanical Transients and Machine Vibrations 3 (3-0) s
Prerequisites: ME 315 or EM 545; MA 512 or MA 402

A study of the forces and motions produced in mechanical systems by periodic and transient inputs including shock and impact loading. Particular attention devoted to the application of the principles of vibration theory to problems encountered in mechanical design.
Messrs. Hart, Whitfield

ME 615 Aeroelasticity I 3 (3-0) f
Prerequisites: MA 511; ME 411 or ME 468; ME 521

Deformations of aero structures under static and dynamic loads, natural mode shapes and frequencies; two and three dimensional incompressible flow, wings, and bodies in unsteady flow; static aeroelastic phenomena.
Mr. Topakoglu

ME 617 Mechanical System Design Analysis 3 (3-0) f
Prerequisites: ME 611, ME 613

Lecture and project activity devoted to development of the ability to apply knowledge and experience in performing comprehensive design analysis of complete mechanical systems. Areas of interest to include critical problem recognition, system modeling, performance determination, and optimization and reliability evaluation. Mr. Zorowski

ME 618 Mechanical System Design Synthesis 3 (3-0) s
Prerequisite: ME 617

Application of the basic philosophy and methodology of the complete design process to advanced mechanical system design. Individual and group experience in the conception, synthesis, analysis, optimization, and implementation phases of feasibility, preliminary, and final design studies provided by means of comprehensive system design projects.
Mr. Zorowski

ME 625, 626 Direct Energy Conversion 3 (3-0) fs
Prerequisite: ME 601

An engineering study of the modern developments in the field of conversion of heat to power in order to meet new technology demands. Thermoelectric, thermomagnetic, thermionic, photovoltaic and magnetohydrodynamic effects and their utilization for energy conversion purposes, static and dynamic response, limitations imposed by the first and the second laws of thermodynamics. Energy and entropy balances, irreversible sources; inherent losses, cascading, design procedures, experimental studies to determine the response and efficiency of various systems. Mr. El-Saden

ME 631 Applications of Ultrasonics to Engineering Research 3 (3-0) f
Prerequisites: MA 511, EE 332

The technique and theory of propagation of ultrasonics in liquids, gases and solids. Development of ultrasonic transducers, the elastic piezoelectric and dielectric relationships. Ultrasonic applications of asdic or sonar cavitation, emulsification, soldering, welding, and acoustic properties of gases, liquids and solids. Mr. Woodburn

ME 651 Principles of Fluid Motion 3 (3-0) f
Prerequisite: ME 453
Corequisite: MA 511

Fundamental principles of fluid dynamics. Mathematical methods of analysis are emphasized. Potential flow theory development with introduction to the effects of viscosity and compressibility. Two dimensional and three dimensional phenomena are considered. Mr. Pinkerton

ME 652 Dynamics of Compressible Flow 3 (3-0) f
Prerequisites: ME 521, MA 511

Properties of compressible fluids, equation of motion in one-dimensional motion, channel flows, shock wave theory, methods of observation, and flows at transonic speeds. Mr. Pinkerton

ME 653 Supersonic Aerodynamics 3 (3-0) s
Prerequisite: ME 652

Equations of motion in supersonic flow, Prandtl-Meyer turns, method of characteristics, hodograph plane, supersonic wind tunnels, supersonic airfoil theory, and boundary layer shock interaction. Mr. Perkins

ME 654 Dynamics of Viscous Fluids I 3 (3-0) f
Prerequisite: ME 521

Exact solutions to the Navier Stokes Equations. Approximate solutions for low Reynolds numbers. Approximate solutions for high Reynolds numbers—incompressible boundary theory. Laminar and turbulent boundary layers in theory and experiment. Flow separation. Mr. Williams

ME 655 Dynamics of Viscous Fluids II 3 (3-0) s
Prerequisite: ME 654

A continuation of ME 654. Compressible laminar and turbulent boundary layers. Laminar and turbulent jets. The stability of laminar boundary layers with respect to small disturbances, transition from laminar to turbulent flow. Mr. Williams

ME 657 Measurement in Rarefied Gas Streams 3 (3-0) f
Prerequisite: ME 602

A study of the basis for measurement of flow properties in rarefied gas streams. Included will be ionization gauges, hot wire anemometers and temperature probes, pitot and static tubes, Langmuir probes, electron scattering and electron beam density gauges. Mr. Smetana

ME 658, 659 Molecular Gasdynamics 3 (3-0) fs

Statistical mechanics as applied to the derivation of the equations of gasdynamics from the microscopic viewpoint. Energy levels of atoms and molecules and their relation to equilibrium thermodynamic concepts, in particular, specific heats. Approximate solutions of the Boltzmann Equation. Treatments of viscosity, heat conduction, and electrical conductivity. Collision processes. High temperature behavior of multispecies gas mixtures. Mr. Smetana

ME 661, 662 Aerospace Energy Systems 3 (3-0) fs
Prerequisites: MA 512, ME 521, PY 407

A study of energy systems appropriate to the varied requirements of space operations. Includes analysis of chemical, nuclear and solar energy sources and the theory of their adaptation to operational requirements for propulsion and auxiliary power, cooling requirements, coolants and materials. Mr. Truitt

ME 671, 672 Advanced Air Conditioning Design I, II 3 (3-0) fs
Prerequisites: ME 571, ME 572

The design of heating and air conditioning systems; the preparation of specifications and performance tests on heating and air conditioning equipment. Mr. Knight

ME 674, 675 Advanced Spacecraft Design 3 (3-0) fs
Prerequisites: ME 542, ME 582

Analysis and design of spacecraft including system design criteria,

acceleration tolerance, entry environment, thermal requirements, criteria for configuration design, aerodynamic design, heating rates, thermostructural design, boost phase, de-orbit, entry corridor, lift modulation, rolling entry, glide phase, maneuvering and landing, stability and control, thermal protection system, materials, instrumentation, and life support systems.
Mr. Truitt

ME 681 Introduction to Rocket Propulsion 3 (3-0) f
Prerequisite: ME 601

Review of the exterior ballistics and performance of rocket propelled vehicles. Thermodynamics of real gases at high temperature. Non-equilibrium flow in rocket nozzles. Mr. Hassan

ME 682 Solid Propellant Rockets 3 (3-0) s
Prerequisite: ME 681

A study of the design and performance of solid-propellant rockets; properties and burning characteristics of solid propellants. Internal ballistics of solid propellant rockets. Design and design optimization. Combustion instabilities. Mr. Hassan

ME 683 Liquid Propellant Rockets 3 (3-0) s
Prerequisite: ME 681

The study and design of liquid propellant rockets. Combustion of liquid fuels. Thrust chamber, propellant supply and injection system. Cooling of rocket motors. Low and high frequency instability in liquid rocket motors. Scaling laws. Mr. Hassan

ME 684 Ion Propulsion 3 (3-0) f or s
Prerequisite: ME 531

Study and design of Ion motors, power sources and converters, missions for ion-propelled vehicles. Mr. Hassan

ME 693 Advanced Topics in Mechanical Engineering 1 to 6 f or s
Prerequisite: Graduate standing

Faculty and graduate student discussions of advanced topics in contemporary mechanical engineering. Graduate Staff

ME 695 Mechanical Engineering Seminar 1 (1-0) f or s

Faculty and graduate student discussions centered around current research problems and advanced engineering theories. Graduate Staff

ME 699 Mechanical Engineering Research Credits by Arrangement
Prerequisite: Graduate standing in mechanical engineering, permission of adviser

Individual research in the field of mechanical engineering.
Graduate Staff

METALLURGICAL ENGINEERING

(For a listing of graduate faculty and departmental information see Department of Mineral Industries, page 159.)

Courses for Advanced Undergraduates

MIM 401, 402 Metallurgical Operations I, II 4 (3-3) fs
Prerequisite: MIM 332

A systematized treatment of the fundamental operations involved in the production and fabrication of metals and alloys. Part I deals primarily with procedures and operations employed in chemical or extractive metallurgy. Part II covers the operations of physical and mechanical metallurgy.

MIM 421, 422 METALLURGY I, II 2 (2-0) fs
Prerequisite: CH 103

The constitution, structure and properties of engineering ferrous and nonferrous metals and alloys; influences of mechanical working and heat treatment; physical testing, corrosion and its prevention.

MIM 423 METALLURGICAL LABORATORY 1 (0-3) fs
Prerequisite: MIM 421 or MIM 422

Laboratory work to accompany Metallurgy I, II.

MIM 431, 432 METALLOGRAPHY I, II 3 (2-3) fs
Prerequisite: MIM 332

An intensive study of the principles and techniques for examination and correlation of the structure, constitution, and properties of metals and alloys.

MIM 491, 492 METALLURGICAL ENGINEERING SEMINAR 1 (1-0) fs
Prerequisite: Senior standing in metallurgical engineering

Reports and discussion of special topics in metallurgical engineering and related subjects.

Courses for Graduates and Advanced Undergraduates

MIM 521, 522 ADVANCED PHYSICAL METALLURGY I, II 3 (3-0) fs
Prerequisite: MIM 422

Theories concerning behavior and control of engineering alloys, reaction rates in the solid state, and alloy influences; current heat treating practices; surface treatments; behavior of metals at high and low temperatures; special purpose alloys; powder metallurgy; review of modern equipment and methods for the study of metals.

Mr. Stadelmaier

MIM 523, 524 METALLURGICAL FACTORS IN DESIGN 3 (3-0) fs
Prerequisite: MIM 422

A study of the metallurgical factors that must be considered in using metals in design. Mr. Austin

MIM 541, 542 PRINCIPLES OF CORROSION I, II 3 (2-3) fs
Prerequisite: MIM 422

The fundamentals of metallic corrosion and passivity. The electrochemical nature of corrosive attack, basic forms of corrosion, corrosion rate factors, methods of corrosion protection. Laboratory work included.

Mr. Austin

MIM 561 ADVANCED STRUCTURE AND PROPERTIES OF MATERIALS 3 (2-3) f
Prerequisite: MIM 422

A systematic treatment of the fundamental physico-chemical principles governing the constitution of both metallic and ceramic materials. Correlation of these principles with physical, mechanical and chemical properties of materials. Particular emphasis is placed upon materials of construction for nuclear reactors. Lectures and laboratory.

Mr. Austin

MIM 562 MATERIALS PROBLEMS IN NUCLEAR ENGINEERING 3 (2-3) s
Prerequisite: MIM 561

Engineering aspects of problems involved in the selection and application of reactor materials. Specific attention is given to elevated temperature behavior, fatigue, corrosion, irradiation damage, and the fabrication and processing of these materials. Lecture and laboratory. Graduate Staff

MIM 595, 596 ADVANCED METALLURGICAL EXPERIMENTS I, II 3 (1-6) fs
Prerequisite: MIM 422 or permission of instructor

Advanced engineering principles applied to a specific experimental

project dealing with metallurgy or metallography. A seminar period is provided and a written report is required. Graduate Staff

Courses for Graduates Only

MIM 651, 652 THEORY AND STRUCTURE OF METALS 3 (3-0) fs
Prerequisite: MIM 522

An advanced interpretation of the development of theories of the metallic state with emphasis on modern physical concepts. Topics include theory of crystallinity, bonding forces, stability of metallic structures, diffusion, and dislocation theory. Mr. Stadelmaier

MIM 691, 692 SPECIAL TOPICS IN METALLURGICAL ENGINEERING 3 (3-0) fs

Special studies of advanced topics in metallurgical engineering. Graduate Staff

MIM 699 METALLURGICAL ENGINEERING RESEARCH Credits by Arrangement

Independent investigation of an appropriate problem in metallurgical engineering. A report on this investigation is required as a graduate thesis. Graduate Staff

DEPARTMENT OF MICROBIOLOGY

GRADUATE FACULTY

Professors: JAMES BRAINERD EVANS, *Head*, WILLIAM VICTOR BARTHOLOMEW, JOHN LINCOLN ETCHELLS, JAMES GIACOMO LEECE, MARVIN LUTHER SPECK

Associate Professors: FRANK BRADLEY ARMSTRONG, WALTER JEROME DOBROGOSZ, GERALD HUGH ELKAN

Assistant Professors: JOHN JOSEPH MCNEILL, JEROME JOHN PERRY

The Department of Microbiology offers programs leading to the Master of Science and Doctor of Philosophy degrees. Both of these degrees require a research thesis on some basic aspect of microbiology under the direction of one of the members of the microbiology faculty listed above.

The graduate programs in microbiology are strongly oriented toward microbial physiology, microbial metabolism and microbial genetics. Students applying for admission to the programs need not have had any formal training in microbiology, but should have a bachelor's or master's degree with a major in one of the biological or physical sciences. Applicants are expected to have completed two semesters of organic chemistry, two semesters of calculus and two semesters of physics with at least C grades. However, students with deficiencies in these areas may be accepted if their record indicates the capability of making it up. Students applying for support in the form of fellowships, traineeships or assistantships should submit scores on the Graduate Record Examination.

At least one semester of experience as a half-time teaching assistant is required for the doctoral degree. As a general rule the master's program requires two calendar years beyond the bachelor's degree and the doctoral program requires two to three years beyond the master's level.

Courses for Advanced Undergraduates

MB 401 General Microbiology 3 (3-0) s
Prerequisites: BS 100, CH 223 or CH 220

A rigorous introduction to the basic principles and concepts of modern microbiology. This course is recommended for students in the biological sciences and agricultural sciences curricula and for all students who plan to take further courses in microbiology. It is generally expected that MB 402 will be taken concurrently. Credit will not be granted for both MB 301 and MB 401.

MB 402 General Microbiology Lab 1 (0-2) s

An introduction to the basic laboratory techniques of microbiology. This will include methods of isolating, culturing, staining, quantitating and characterizing pure cultures of microorganisms. There will be one 2-hour formal lab period and students will be expected to come in briefly at other times to make observations.

Courses for Graduates and Advanced Undergraduates

MB 501 Advanced Microbiology 3 (3-0) f
Prerequisites: CH 223 or CH 220, MB 402

A rigorous introduction to topics in basic microbiology that are not considered in depth in MB 401. These include microbial cell composition and structure, the function of subcellular units, microbial classification, microbial genetics, and pathogenic microbiology. It will be complementary immunological methods, work with bacteriophage, tissue cultures, etc. currently.

Mr. Perry

MB 502 Advanced Microbiology Lab 2 (0-4) f
Prerequisite: MB 402

This course introduces the student to many of the techniques and instruments commonly employed in research with microorganisms. It will include measurement of growth and metabolic activities, cell fractionation, immunological methods, work with bacteriophage, tissue celutures, etc.

Mr. Perry

MB 505 See FS 505, Food Microbiology. 3 (2-3) s

MB 506 See FS 506, Advanced Food Microbiology. 3 (0-9) f

MB 514 Microbial Physiology 3 (3-0) s
Prerequisites: CH 223 or CH 220, CH 551, MB 401

A consideration of the processes of cell physiology that are of particular significance in microorganisms. Included will be a study of cell structure, growth, death, reproduction, nutrition, metabolism, and regulatory mechanisms.

Mr. Dobrogosz

MB 532 See SSC 532, Soil Microbiology. 3 (3-0) s

MB 555 See ZO 555, Protozoology. 4 (2-6) f

MB 561 See GN 561, Biochemical and Microbial Genetics. 3 (3-0) f

MB 570 See CE 570, Sanitary Microbiology. 3 (2-3) s

MB 574 See BO 574, Phycology. 3 (1-4) s

MB 575 See BO 575, The Fungi. 4 (3-3) s

MB 590 Topical Problems Credits by Arrangement fs
Graduate Staff

Courses for Graduates Only

MB 614	See ANS 614, Bacterial Metabolism.	2 (2-0) s
MB 690	Microbiology Seminar	1 (1-0) fs Graduate Staff
MB 692	Special Problems in Microbiology	Credits by Arrangement fs Graduate Staff
MB 699	Microbiology Research	Credits by Arrangement fs Graduate Staff

DEPARTMENT OF MINERAL INDUSTRIES

GRADUATE FACULTY

Professors: William Wyatt Austin, *Head,* William Callum Bell, William Cullen Hackler, William Wurth Kriegel, Carlton James Leith, Hayne Palmour, III, John Mason Parker, III, Hans Heinrich Stadelmaier, Robert Franklin Stoops

Adjunct Professor: Henry Mauzee Davis

Visiting Professor: Joachim-Dietrich Schobel

Associate Professors: Henry Seawell Brown, John Valentine Hamme, Charles William Welby

Adjunct Associate Professor: James Kitchener Magor

The Department of Mineral Industries offers graduate programs leading to the degrees of Master of Science in ceramic engineering, geological engineering, and metallurgical engineering, and to the Doctor of Philosophy degree in ceramic engineering. Certain graduate courses are also offered for the benefit of students majoring in other areas who may be interested in pursuing advanced work in the mineral industries fields.

Financial assistance is available to qualified graduate students in the Department of Mineral Industries. Graduate assistantships permit half-time studies in either ceramic engineering, geological engineering, or metallurgical engineering, and half-time to be devoted to teaching or research. Also, certain sponsored fellowships and traineeships that permit full time to be devoted to graduate studies are available on a competitive basis. Applications should be made to the department.

CERAMIC ENGINEERING

The unique characteristics of ceramics qualify them for many advanced engineering applications in space, nuclear, and industrial technologies. Rapid expansion of this important materials discipline present challenging opportunities for engineering and research. Advanced study is fast becoming a prerequisite for careers in significant growth areas. North Carolina State University has been actively engaged in post graduate teaching and research for more than three decades and since 1950, has been the only institution in the southeast offering the Doctor of Philosophy degree in ceramic engineering. Recruitment for stimulating employment by nationally prominent

industrial, educational, and governmental organizations consistently outstrips available graduate degree recipients many fold.

The graduate program is predicated upon acquisition of fundamental understanding of the combined influence of material chemistry, defect structure in the solid state, process selection and kinetics, microstructure, environment, and service conditions upon the ultimate performance of ceramic products. The research interests of the graduate faculty currently encompass a broad spectrum of the ceramic field. Included are materials synthesis, processing kinetics, phase relationships, constitution and structure, mechanical and dielectric properties of crystalline and vitreous materials, and design, development and applications of ceramics and ceramic composites.

Well equipped laboratories for graduate instruction and research are in active use and are being systematically enlarged and improved. Broad interdisciplinary strengths are based upon related material activities in several other curricula in the School of Engineering and other schools of the University.

The prerequisite for graduate study in ceramic engineering is a proficiency in undergraduate courses leading to the bachelor's degree in ceramic engineering, or a substantial equivalent. A significant fraction of the current student body have come to ceramics with backgrounds in other science and engineering disciplines.

For course descriptions, see Ceramic Engineering, page 59.

GEOLOGICAL ENGINEERING

The graduate program in geological engineering is directed to the advanced training of qualified students interested in the professional economic applications of geological knowledge. The occupational fields include the locating of mineral resources, and the assessing of geological conditions at the sites of large civil engineering projects. Candidates for admission to this program should hold the Bachelor of Geological Engineering degree or a satisfactory equivalent, preferably including a strong background in physics, chemistry, and engineering sciences.

The solution of professional problems in geology is today requiring more specialized training and quantitative methods than can be included in an undergraduate curriculum. A person with such training in geology finds employment with petroleum, mining, and construction companies, governmental agencies, and educational research institutions.

A great variety of problems in igneous, sedimentary, and metamorphic geology are to be found within a radius of fifty miles of North Carolina State University.

Facilities are available for research in mineralogy, petrography, economic geology, mineral dressing, and geologic problems relating to civil engineering. Excellent collections of geological literature are available at North Carolina State University, at the University of North Carolina at Chapel Hill, and at Duke University in Durham.

A well staffed unit of the General Hydrology division of the U. S. Geological Survey is housed on the campus and is available for consultation.

For course descriptions, see Geological Engineering, page 126.

METALLURGICAL ENGINEERING

The rapid development of space and nuclear technology and attendant materials problems has brought about a sharp increase in the demand for trained leaders in the materials fields. There is at present intense emphasis on advanced study and research on the fundamental behavior of metals and alloys. From this work will come urgently-needed improvements in metallic materials of construction to withstand increasingly drastic service requirements—higher stresses, higher temperatures, corrosive and radioactive environments.

Opportunities for men with graduate training in metallurgy and metallurgical engineering are almost unlimited. Industry and universities today need approximately four times as many metallurgists with advanced degrees as are available. It has been estimated that by 1975 the electrical, chemical, aerospace, and nuclear industries will require 50,000 research metallurgists and metallurgical engineers. The number presently available is approximately 10,000. Present ratios indicate that one-third to one-half of the 50,000 graduates needed should have advanced training beyond the bachelor's degree. The shortage of graduates with advanced degrees is further accentuated by the need for qualified college faculty members to provide adequate instruction in metallurgical and related fields.

North Carolina State University is one of the few institutions in the South, and the only institution in North Carolina, prepared to offer graduate instruction in metallurgical engineering. In this program special emphasis is placed upon the application of basic physical metallurgy to problems encountered in various engineering disciplines including mechanical design, corrosive and reactive environments, and nuclear reactor applications. Appropriate opportunities for graduate thesis research are available in each of these areas. In addition to the advanced work in metallurgical engineering, the School of Engineering also offers an excellent program of supporting courses at the graduate level in the related fields of physics, chemistry, mathematics, engineering mechanics, and in mechanical, chemical, ceramic, and nuclear engineering.

For course descriptions, see Metallurgical Engineering, page 155.

DEPARTMENT OF MODERN LANGUAGES

GRADUATE FACULTY

Professors: GEORGE WAVERLY POLAND, *Head,* EDWARD M. STACK

The Department of Modern Languages offers courses to assist graduate students in preparing themselves to use modern foreign lan-

guages in research and advanced study. Students are given the opportunity of working a translation project in connection with their subject of major interest. They are encouraged particularly to seek useful foreign research related to their thesis or other research in progress. Although these courses do not carry graduate language credit, they may be taken as a means of attaining a reading knowledge.

Certification may be obtained in languages not normally taught by the department with special permission of the Graduate School.

MLR 101 ELEMENTARY RUSSIAN 3 (3-0) fs

MLR 102 RUSSIAN GRAMMAR AND PROSE READING 3 (3-0) fs
Prerequisite: MLR 101 or equivalent

MLF 401 FRENCH GRAMMAR FOR GRADUATE STUDENTS 3 (3-0) fs

This course is designed to present the grammar of scientific French as rapidly as possible in preparation for the reading course which follows.

MLF 402 SCIENTIFIC FRENCH 3 (3-0) fs
Prerequisite: MLF 401 or equivalent

Reading and translation of technical French, supplemented by discussion on terminology, word order, vocabulary analysis and other linguistic techniques. Subject material adjusted to individual needs; conferences.

MLS 401 SPANISH GRAMMAR FOR GRADUATE STUDENTS 3 (3-0) fs

This course is designed to present the grammar of scientific Spanish as rapidly as possible in preparation for the reading course which follows.

MLS 402 SCIENTIFIC SPANISH 3 (3-0) fs
Prerequisite: MLS 401 or equivalent

Reading and translation of technical Spanish, supplemented by discussions on terminology, word order, vocabulary analysis and other linguistic techniques. Subject material adjusted to individual needs; conferences.

MLG 401 GERMAN GRAMMAR FOR GRADUATE STUDENTS 3 (3-0) fs

This course is designed to present the grammar of scientific German as rapidly as possible in preparation for the reading course which follows.

MLG 402 SCIENTIFIC GERMAN 3 (3-0) fs
Prerequisite: MLG 401 or equivalent

Reading and translation of technical German, supplemented by discussions of terminology, word order, vocabulary analysis and other linguistic techniques. Subject material adjusted to individual needs; conferences.

DEPARTMENT OF NUCLEAR ENGINEERING

GRADUATE FACULTY

Professors: RAYMOND L. MURRAY, *Head,* RAYMOND F. SAXE

Adjunct Professor: RALPH L. ELY

Associate Professor: THOMAS S. ELLEMAN

Assistant Professors: ALBERT H. CARNESALE, MARTIN A. WELT, CHARLES E. SIEWERT

Affiliated Graduate Faculty

Professors: WESLEY O. DOGGETT (Physics), MUNIR R. EL-SADEN (Mechanical Engineering), JAMES K. FERRELL (Chemical Engineering), CHARLES SMALLWOOD, JR. (Civil Engineering), ARTHUR W. WALTNER (Physics)

Associate Professors: LAWRENCE H. BOWEN (Chemistry), ALONZO F. COOTS (Chemistry), ROBERT W. LADE (Electrical Engineering), EDWARD G. MANNING (Electrical Engineering), M. NECATI OZISIK (Mechanical Engineering)

The Department of Nuclear Engineering offers graduate study leading to the Master of Science and Doctor of Philosophy degrees.

Courses and research are available within the department and cooperating departments in several areas of nuclear engineering, including reactor theory and analysis, radiation attenuation and detection, radiation effects, energy transfer and conversion, nuclear materials, nuclear safety and instrumentation, and radiation applications.

Among the available research facilities are: a 100-kilowatt heterogeneous tank-type reactor; a 30-kilocurie cobalt gamma irradiation source; a natural uranium subcritical assembly; a 1-Mev pulsed Van de Graaff accelerator; a pulsed neutron generator; laboratories for neutron activation analysis; radiochemistry and gaseous discharges; a high pressure heat transfer loop; and digital and analog computers.

Candidates for admission are expected to hold the bachelor's degree in one of the fields of engineering or the physical sciences. Experience in nuclear physics, advanced differential equations, and basic reactor theory will reduce the time required for completion of the degree. Courses in these areas can be included in the initial phases of the graduate program. Thirty credit hours (including four for research) and a thesis are required for the Master of Science degree. Well-qualified students may study directly toward the Doctor of Philosophy degree. Interdisciplinary research programs may be arranged for graduate students in cooperation with departments in the Schools of Engineering, Physical Sciences and Applied Mathematics, and Agriculture and Life Sciences.

The Department of Nuclear Engineering participates in the Nuclear Science and Engineering Fellowship Program of the Atomic Energy Commission. Students are also eligible for fellowships from the Ford Foundation, the National Science Foundation, the National Aeronautics and Space Agency, and others. Half-time graduate teaching or research assistantships are available in which a nine credit-hour load per semester is permitted.

Graduates of the department find positions in industry, government, and academic institutions. Opportunities include analysis, design, utilization, and operation of nuclear facilities associated with the nuclear aerospace program, power reactors, research reactors, and radioisotopes.

Courses for Advanced Undergraduates

NE 404 NUCLEAR ENERGY CONVERSION I 3 (3-0) s
Prerequisite: CHE 421 or equivalent

Basic principles of the transformation of nuclear energy into useful forms. Considers the reactor as a heat source for a heat engine cycle. Description and analysis of various reactor concepts and associated power plants.

NE 405 Nuclear Energy Conversion II 3 (3-0) f
Prerequisite: CHE 422 or equivalent

Basic principles of the transformation of nuclear energy into useful forms. Considers isotope production and utilization, direct conversion techniques, nuclear propulsion concepts, research reactors, and breeder reactors.

NE 419 Introduction to Nuclear Engineering 3 (3-0) f
Prerequisite: PY 407

A survey of nuclear energy applications, including nuclear reactor materials, reactor theory, shielding, thermal and hydraulic analysis, and control. Uses of nuclear fission and its by-products in research, industry and propulsion are reviewed. The major engineering problems are defined and methods of approach are outlined. Staff

Courses for Graduates and Advanced Undergraduates

NE 501 Nuclear Reactor Theory I 3 (3-0) f
Corequisite: PY 410

An introductory course in reactor theory including the fission process, neutron energy distribution, lethargy, neutron slowing and interactions, diffusion, Fermi age theory, the diffusion equation, criticality conditions, and reactor instrumentation. Messrs. Siewert, Verghese

NE 502 Nuclear Reactor Theory II 3 (3-0) s
Prerequisite: NE 501

Continuation of reactor theory from NE 501. Topics include: treatment of reactor parameters for homogeneous and heterogeneous reactors, reflected reactors, multi-group theory, reactor kinetics, temperature effects, control rod theory, perturbation theory, and transport theory.
Messrs. Siewert, Verghese

NE 503 Nuclear Engineering Systems 3 (3-0) s
Prerequisite: NE 501

Considers reactor as a system including aspects of reactor control, radiation protection, shielding, and thermal design. Mr. Carnesale

NE 511 Radiation Detection and Analysis 3 (1-4) fs
Prerequisite: PY 410

Interaction of radiation with detectors. Characteristics of detectors and analysis equipment. Statistics of the counting process. Emphasis is on preparation for use of radiation counting equipment for research.
Mr. Verghese

NE 518 Radiological Safety 3 (3-0) s
Prerequisites: PY 410, NE 501

Treatment of types of radiation and their interaction with matter, shielding and biological effects. Study of safety considerations in a nuclear installation, including regulations, instrumentation used, overall detection system, emergency situations, and radiation containment.
Mr. Elleman

NE 520 Nuclear Radiation Shielding 3 (3-0) f
Prerequisite: NE 503

An introduction to radiation protection criteria, design of shields for attenuation of gamma rays and neutrons from reactor primary systems and other sources and shield materials. Machine computation techniques will be discussed whenever necessary. The latter part of the semester will be utilized to carry out special problems in the design of space-radiation shields, hot cells and fall-out shelters. Mr. Carnesale

NE 530 Introduction to Nuclear Reactor Theory 3 (3-0) fs
Prerequisite: PY 410

The principles of neutron motion in matter, with emphasis on the analysis of the nuclear chain reactor. Slowing of neutrons, diffusion, space distributions of flux, conditions for criticality, group theories, and the time-dependent behavior of fissionable assemblies. Mr. Verghese

NE 531 Nuclear Reactor Laboratory 2 (0-6) fs
Prerequisite: NE 530 or NE 501

Observation and measurements of static and dynamic nuclear reactor behavior, the effectiveness of control and temperature, and correlation with theory. Experiments on the motion and detection of neutrons and gamma rays, with emphasis on the research uses of nuclear reactor radiations. Mr. Verghese

NE 532 Nuclear Engineering Laboratory 2 (0-6) s
Prerequisite: NE 501 or equivalent

A laboratory course that provides a series of experiments that are fundamental to nuclear engineering. Special emphasis will be on experiments related to nuclear reactor theory, reactor kinetics, neutron physics, reactor heat transfer and radiochemistry applications. Several experiments in conjunction with an analog computer will be performed. Familiarization with research equipment will be gained through active participation of the student in setting up the various measurements. Mr. Saxe

NE 540 Nuclear Reactor Control 3 (3-0) s
Prerequisite: NE 502 or NE 530

Considers non-steady-state reactor behavior including reactivity effects due to temperature, poisoning, and control rods. Uses elementary servomechanism theory in treating reactor as a control element. Treats automatic control including control mechanisms and dynamic effect of power plant characteristics. Mr. Saxe

NE 545 Nuclear Reactor Kinetics 3 (3-0) f
Prerequisite: NE 502 or NE 530

The kinetic behavior of nuclear reactors is carefully analyzed from both theoretical and experimental viewpoints. Solutions of the basic kinetic equations are developed and applied to specific reactor behavior. Temperature, void, and xenon poisoning effects are considered. Digital and analog computer techniques are discussed and utilized. Correlation of theory with observed reactor behavior is made and safety considerations in reactor design are discussed. Mr. Saxe

NE 550 Radiation Utilization 3 (3-0) f
Prerequisites: PY 410, NE 511 or equivalent

Theory, industrial application, and economics of nuclear radiation are discussed. Emphasis is on the ability to choose appropriate forms of radiation and to design practical equipment. Subjects covered include: origin and economics of radiation, tracer techniques, activation analysis, food irradiation, chemonuclear processing, low and high level sealed source devices, and unique engineering aspects. Messrs. Ely, Welt

NE 570 Radiation Effects on Materials 3 (3-0) f
Prerequisites: MIM 201, PY 407

A study of the interactions of different types of radiation with matter, with emphasis on the physical effects. Current theories will be evaluated and experimental techniques will be discussed. Annealing of defects and radiation-induced changes in physical properties will be investigated in detail. Mr. Elleman

NE 591, 592 Special Topics in Nuclear Engineering I, II 3 (3-0) fs
Prerequisite: Permission of instructor

These courses will be used to explore unusual and/or specialized areas of nuclear engineering. Graduate Staff

Courses for Graduates Only

NE 619 Reactor Theory and Analysis I 3 (3-0) f
Prerequisite: NE 502 or NE 530

The theory of neutron slowing, resonance capture, Doppler effect, and thermal flux distributions in heterogeneous nuclear reactors. Analysis of reactor control by temperature, effects of localized and distributed absorbers, fission products, fuel consumption and production. One-velocity neutron transport theory. Mr. Murray

NE 620 Nuclear Radiation Attenuation 3 (3-0) f
Prerequisite: NE 503

The physical theory and mathematical analysis of the penetration of neutrons, gamma-rays, and charged particles. Analytical techniques include point kernels, transport theory, Monte Carlo, and numerical methods. Digital computers are employed in the solution of practical problems.
Mr. Carnesale

NE 630 Reactor Theory and Analysis II 3 (3-0) s
Prerequisite: NE 502 or NE 530

The theory of neutron multiplication in uniform media with several dimensions, regions, and neutron energy groups. Reactor control by absorbers, time dependent reactor behavior, matrix treatment or perturbation theory, neutron thermalization, energy dependent neutron transport theory, and multigroup machine methods. Mr. Murray

NE 651 Advanced Reactor Theory 3 (3-0) s
Prerequisite: NE 619 or NE 630

A presentation of the latest advances in the mathematical analysis of nuclear systems behavior, with special emphasis on Case's method of singular eigenfunctions. Exact solutions to several classical problems in transport theory are constructed. The relation of experimental measurements, theoretical interpretation, and numerical computation methods will be discussed. Mr. Siewert

NE 653 Nuclear Reactor Design 3 (3-0) s
Corequisites: NE 619, NE 630

A comprehensive analysis and design of a nuclear reactor system for a specified application will be performed. Considerations will include criticality, control, lifetime, thermal-hydraulic, shielding, economics, power conversion, and optimization procedures. Selected applications will be varied each year. Mr. Saxe

NE 691, 692 Advanced Topics in Nuclear Engineering I, II 3 (3-0) fs
Prerequisite: Permission of instructor

A study of recent developments in nuclear engineering theory and practice. Graduate Staff

NE 695 Seminar in Nuclear Engineering 1 (1-0) fs

Discussion of selected topics in nuclear engineering. Graduate Staff

NE 699 Research in Nuclear Engineering Credits by Arrangement

Individual research in the field of nuclear engineering.
Graduate Staff

DEPARTMENT OF OCCUPATIONAL INFORMATION AND GUIDANCE

GRADUATE FACULTY

Professor: Roy Nels Anderson, *Head*
Associate Professor: Charles G. Morehead
Assistant Professor: Jack Albert Duncan

The Department of Occupational Information and Guidance has been training guidance and personnel workers for more than four decades. The first master's degree was awarded in 1926. The programs of graduate study are planned to develop a broad understanding of guidance and personnel services to be applied in various settings. It is most desirable for an applicant who wishes to specialize in guidance and personnel services to have had undergraduate course work in economics, education, psychology, sociology or social work. Students accepted into the program are those who anticipate devoting full or part-time to guidance and personnel work. Teachers, administrators and others who wish to increase their knowledge of guidance and personnel may enroll for courses as a graduate minor or for certification renewal.

Professional opportunities for placement in this field are on the increase. The department prepares students for positions as counselors in secondary schools, industrial education centers, colleges, community agencies, school or county guidance directors, rehabilitation counselors, employment counselors, placement interviewers, and personnel workers in higher education, business or industry, and state and federal government agencies. The student may specialize in one of several areas depending upon his career goals.

The master's program includes a core of guidance and personnel courses to be selected according to the student's vocational goals. Students may select their minor from the following areas: economics, psychology, sociology and anthropology and educational administration. The master's degree program of the department meets the requirements for the Counselor's Certificate issued by the North Carolina State Department of Public Instruction, as well as counselor certification in many other states.

The Department of Occupational Information and Guidance has had a contract with the Office of Vocational Rehabilitation for the training of rehabilitation counselors, and has been awarded five Counseling and Guidance Training Institutes under contract with the United States Office of Education as authorized by the National Defense Education Act of 1958.

The department also provides service courses in guidance and personnel for undergraduate students in the School of Education.

A limited number of graduate assistantships are available annually in the department and through the Division of Student Affairs.

Courses for Graduates and Advanced Undergraduates

ED 520 Personnel and Guidance Services 3 (3-0) f
Prerequisite: Six hours of education or psychology

An introduction to the philosophies, theories, principles, and practices of personnel and guidance services; the relationship of personnel services with the purposes and objectives of the school and the curriculum.

Mr. Duncan

ED 524 Occupational Information 3 (3-0) s
Prerequisites: Six hours of education or psychology, ED 520 or equivalent

This course is intended to give teachers, counselors, placement workers, and personnel workers in business and industry an understanding of how to collect, classify, evaluate, and use occupational and educational information. This will include a study of the world of work, sources of occupational information, establishing an educational-occupational information library, using educational, occupational, and social information, and sociological and psychological factors influencing career planning. Mr. Duncan

ED 530 Group Guidance 3 (3-0) f
Prerequisites: Six hours of education or psychology, ED 520 or equivalent

This course is designed to help teachers, counselors, administrators, and others who work with groups, or who are responsible for group guidance activities, to understand the theory and principles of effective group work, to develop skill in using specific guidance techniques, and to plan and organize group activities in the secondary school and other institutions.
Mr. Morehead

ED 533 Organization and Administration of Guidance Services 3 (3-0) s
Prerequisites: Graduate standing, ED 520 or equivalent

This course is designed for school guidance counselors, prospective counselors, personnel and guidance directors, and school administrators. The philosophy and scope of guidance and personnel services; the functions and responsibilities of personnel involved; basic principles and current practices in planning, developing, operating, and supervising guidance and personnel services will be studied. Administrative relationships, utilization of school staff, interrelationships of guidance services with instruction, and evaluation of guidance services will be considered. Mr. Morehead

ED 590 Individual Problems in Guidance Maximum 6 fs
Prerequisite: Six hours graduate work in department or equivalent

Intended for individual or group studies of one or more of the major problems in guidance and personnel work. Problems will be selected to meet the interests of individuals. The workshop procedure will be used whereby special projects, reports and research will be developed by individuals and by groups. Graduate Staff

Courses for Graduates Only

ED 631 Educational and Vocational Guidance 3 (3-0) f
Prerequisite: Nine hours from following fields—economics, education, psychology or sociology

The development of a philosophy and point of view of vocational guidance from an interdisciplinary approach—economics, education, psychology and sociology. The course aims to provide basic understandings for counselors in educational settings, employment offices, personnel workers, rehabilitation settings and social workers, who are aiding individuals with vocational decision making and vocational adjustment problems. The course will cover the basic functions performed in vocational and educational guidance.
Mr. Anderson

ED 633 Techniques of Counseling 3 (3-0) s
Prerequisite: Nine hours from following fields—economics, education, psychology or sociology

This course is designed to aid the personnel worker in the secondary school, college, employment office, social agency to develop an understanding and to develop skill in counseling techniques; philosophies, theories, principles and practices of counseling will be considered. Students will become acquainted with counseling techniques through lectures, demonstrations, case histories and tape recordings. Attention will be given to both diagnosis and treatment. Mr. Anderson

ED 641 Laboratory and Practicum Experiences in Counseling 2-6 fs
Prerequisite: Advanced graduate standing

A practicum course in which the student participates in actual counseling experience under supervision in a school, college, social service agency, employment office, and business or industrial establishment. The student may observe and participate in some personnel and guidance services and may study the organization and administration of the program.

Messrs. Anderson, Duncan, Morehead

OPERATIONS RESEARCH

(An inter-departmental graduate program.)

GRADUATE FACULTY

Technical Committee:

Professors: Robert Gordon Carson, Jr., *Chairman*, Richard Loree Anderson, John Francis Bogdan, Frederick Phillips Brooks, Jr., Arthur Raymond Eckels, Robert Warren Llewellyn, George Edward Nicholson, Jr.

Associate Professor: Cleon Harrell

Assistant Professor: David Allen Link

Associated Faculty:

Professors: Clifton A. Anderson, William John Barclay, Arnold Herbert Edward Grandage, Robert John Hader, Richard Adams King, Robert James Monroe, Bernard Martin Olsen, Charles Harry Proctor, Hans Sagan, Walter Laws Smith, Ernst Warner Swanson, Hubertus Robert Van Der Vaart, Oscar Wesler

Adjunct Professor: P. Gene Smith

Visiting Professor: Makoto Itoh

Associate Professors: Raul Eduardo Alvarez, Norman Robert Bell, John William Bishir, William Ray Henry, Laurence Jay Herbst, Wilbur Carroll Peterson, Richard Lee Simmons, Thomas Dudley Wallace

Assistant Professors: Bibhuti Bhushan Bhattacharyya, William Sylvan Galler, Edward Hempstead Wiser

Successful operation of any enterprise, commercial or public, depends on the ability of the managers to foresee the consequences of putting into effect any of the alternative courses of action available to them. For example, the manager of a factory producing several different products has to decide what quantity of each product to produce. Of course, he is limited in the resources available, e.g. plant, liquid assets, raw materials and labor, and also by the demand for the several products. Even so, there generally will be several different and feasible production schedules. The manager's problem is to choose the production schedule most advantageous to the factory, usually that yielding the largest profit.

The problems arising in this context, of which the above is a typical example, are many and varied. It has been recognized that many of these problems have representations in mathematical form, and a number of methods and techniques (linear programming, dynamic programming, theory of queues, simulation, etc.) have been developed for solving the corresponding mathematical problems. Operations Research consists of these problems, the techniques for solving them and research aimed at recognizing new problems and finding new solutions.

At North Carolina State University at Raleigh and the University of North Carolina at Chapel Hill, graduate courses in many areas of operations research have been offered by various departments on the two campuses for a number of years. In addition, numerous operations research theses have been directed by staff members of these departments. Recognizing the need to coordinate and expand these activities, an Operations Research Technical Committee has been appointed, consisting of representatives from the Departments of Statistics and Information Science at Chapel Hill and the Departments of Biological and Agricultural Engineering, Economics, Electrical Engineering, Experimental Statistics, Industrial Engineering, Mathematics and Textile Technology at Raleigh.

After reviewing the operations research programs of many well-known institutions and taking account of the indicated needs for personnel, the technical committee decided that each member of an operations research team should contribute strength in at least one basic discipline. Hence it was decided to establish a strong graduate *minor program in Operations Research*, with the major in *any* basic discipline which could contribute to or utilize these techniques. The operations research graduate courses are to be selected from the following general areas:

Control Systems and Reliability
Econometrics and Economic Decision Making
Information and Computer Science
Mathematical Techniques for Optimization
Probability and Statistics

If a student majors in a discipline which includes one of these areas, he would be expected to take courses from this area as a part of the major and select the operations research minor courses from other areas. The cohesive elements in the graduate program are to be a seminar and a special topics course.

The minimal course requirements for graduate minors in operations research are as follows:

Master's Degrees. The special topics course and seminar plus two courses in one of the five operations research areas.

Doctoral Degrees. The special topics course and seminar plus five other courses, with at least two courses from each of two operations research areas.

Prospective students should pay particular attention to the prerequisites for the courses chosen. A student minoring in operations research should have a good background in matrix algebra, advanced calculus and introductory probability, or be prepared to take such courses early in his graduate program. The Departments of Electrical Engineering and Industrial Engineering have developed one-semester courses (EE 430, Essentials of Electrical Engineering; IE 510, Industrial Engineering Methods) to qualify non-engineers to enter certain courses in the areas of control systems and reliability and information and

computer science. Such background courses cannot be counted as part of the operations research minor program.

Both teaching and research assistantships are available to qualified applicants each year from the departments represented on the technical committee. Requests for such assistance or for information on the operations research program should be directed to these departments or to the chairman of the technical committee.

Courses for Graduates Only

OR 691 Special Topics in Operations Research 3 (3-0) s
Prerequisites: MA 405, MA 511, MA 541 (ST 541), enrolled for operations research minor

Case studies exemplifying a variety of operations research applications. Students will devote three to five weeks per case and will work in small groups under the supervision of operations research faculty members. Required of students with an operations research minor. Graduate Staff

OR 695 Seminar in Operations Research 1 (1-0) f
Prerequisite: Enrolled for operations research minor

Seminar discussion of operations research problems. Case analyses and reports. Graduate students with minors in operations research are expected to attend throughout the period of their residence. Graduate Staff

ST 202 See UNC ST 202, Methods of Operations Research.

Courses in Cooperating Departments *

Control Systems and Reliability

EE 516 Feedback Control Systems
EE 613 Advanced Feedback Control
IE 522 Dynamics of Industrial Systems
IE 547 Engineering Reliability
IE 621 Inventory Control Methods

Econometrics and Economic Decision Making

EC 523 Planning Farm and Area Adjustments
EC 550 Mathematical Models in Economics
EC-ST 651 Econometric Methods I
EC-ST 652 Econometric Methods II
EC 665 Economic Behavior of the Organization

Information and Computer Science

EE 506 Dynamical Analogies
EE 512 Communication Theory
EE 642 Automata and Adaptive Systems
EE 651 Statistical Communication Theory
IS 160 Introduction to Automatic Digital Control
IS 204 Tutorial in Architecture of Computers
IS 210 Processing of Natural and Artificial Languages
IS 211 Tutorial in Information Retrieval
MA 536 Logic for Digital Computers
MA 537 Non-numeric Uses of Computers
ST 252 Information Theory
ST 253 Error Correcting Codes

* Courses with numbers beginning with 1 or 2 are taught on the Chapel Hill campus; others are taught at Raleigh.

Mathematical Techniques of Optimization

IE 505 (MA 505) Mathematical Programming I
ST 606 (MA 606) Mathematical Programming II
IE 607 (MA 607) Special Topics in Mathematical Programming
MA 581 Special Topics

Probability and Statistics

MA 542 (ST 542) Theory of Probability II
ST 132 Intermediate Probability
ST 613, 614 Time Series Analysis I, II
ST 617, 618 (MA 617, 618) Measure Theory and Advanced Probability
ST 619 (MA 619) Topics in Advanced Probability
ST 235 Stochastic Processes

DEPARTMENT OF PHILOSOPHY AND RELIGION

Courses for Advanced Undergraduates

PHI 401 Symbolic Logic 3 (3-0) f

Modern methods in logic involving formalized expression that avoids inherent difficulties and ambiguities of ordinary language and makes possible greater effectiveness in handling complex material.

REL 403 Religions of the World 3 (3-0) s

Background, general characteristics, and basic teachings of the major living religions of the world; consideration of contemporary secular movements that are in a sense religions.

PHI 405 Foundations of Science 3 (3-0) fs

Nature and validity of knowledge, basic concepts of modern science, scientific method, and the implications of the philosophy of modern science for ethics, social philosophy, and the nature of reality.

DEPARTMENT OF PHYSICS

GRADUATE FACULTY

Professors: Lewis Worth Seagondollar, *Head,* Willard Harrison Bennett, Wesley Osborne Doggett, Harry Charles Kelly, Forrest Wesley Lancaster, Joseph Thomas Lynn, *Graduate Administrator,* Edward Raymond Manring, Jefferson Sullivan Meares, Arthur Clayton Menius, Jr., Raymond Leroy Murray, Arthur Walter Waltner

Professor Emeritus: Rufus Hummer Snyder

Associate Professors: William Robert Davis, Jasper Durham Memory, Marvin Kent Moss

Assistant Professors: Grover Cleveland Cobb, Jr., Gerald Howard Katzin, David Hamilton Martin, Jae Young Park, George William Parker, III, Richard Roland Patty

Study in physics leading to the degrees Master of Science and Doctor of Philosophy is available. Courses, staff, and facilities are provided for presentation of the fundamental subject matter of physics and for specialized study and research in several areas, as listed below:

Nuclear Physics: Theoretical and experimental work in the fields of low energy charged-particle physics, neutron physics, and the statistical behavior of nuclear processes.

Space Physics: Research on phenomena in the upper atmosphere and interplanetary space.

Plasma Physics: Studies of basic ionic processes and applications to thermonuclear research.

Infrared Studies: Research on transmission of radiation through planetary atmospheres and spectroscopic investigations of molecular and solid-state structures.

Lasers: Theoretical and experimental work on the irradiation of laser crystals, and studies relating to new laser materials.

Theoretical Physics: Theory of fields, non-inertial systems, nuclear structure and interactions, plasmas, molecular spectroscopy, and solid state.

Nuclear Magnetic Resonance Spectroscopy: Theoretical and experimental studies of polycyclic hydrocarbons.

Programs of study leading to the Master of Science degree are available requiring a minimum of 30 credits, including four credits of research and two of seminar. The presentation of a thesis is also required.

The Doctor of Philosophy degree is granted on successful completion of examinations, independent research, and the submission of a dissertation. A minor in mathematics or other area in science is normally elected.

All graduate students and staff are expected to attend a weekly departmental colloquium at which topics of current interest in physics are discussed.

Extensive laboratory facilities are available for research in the areas of specialization. These facilities include:

(a) A 1-Mev Van de Graaff accelerator with pulsing equipment for study of neutron scattering, polarization, and diffusion.
(b) A hypersonic ionic wind tunnel for study of simulated space environments.
(c) A plasma physics laboratory supported by a research tube-making facility for the investigation of the stability of ion streams.
(d) Laboratories for research in magneto-optical effects, radiation detection, and radiation dosimetry.
(e) Laboratories for laser research equipped with a Cary Instruments Model 14 recording spectrometer and Cobalt-60 irradiator.
(f) Laboratories for infrared spectroscopy and studies of synthetic planetary atmospheres and the upper atmosphere.
(g) A Varian Associates Model HA100 high resolution nuclear magnetic resonance spectrometer with a proton stabilization loop.

(h) The IBM 1410 Tape System, located in the Computing Center, is available for use in research by graduate students. The Computing Center also offers non-credit short courses in FORTRAN programming. Plans include the acquisition of IBM system/360 equipment.

The Department of Physics participates in the Nuclear Science and Engineering Fellowship program of the Atomic Energy Commission, and Fellowships in Health Physics are currently available under a continuing grant from the U. S. Public Health Service. Students are also eligible for fellowships from the Ford Foundation, the National Science Foundation, the National Aeronautics and Space Administration, the National Defense Education Act, and others. Research assistantships are available supported by grants or contracts with federal agencies, and a number of halftime teaching assistantships in general and intermediate physics is available each year.

Research work on nuclear chain reacting systems and on the attenuation of nuclear radiation in matter is conducted cooperatively with the Department of Nuclear Engineering. Research in biophysics is done cooperatively with the Institute of Statistics.

Courses for Advanced Undergraduates

PY 407 Introduction to Modern Physics 3 (3-0) fs
Prerequisites: PY 208, MA 202

A survey of the important developments in atomic and nuclear physics of this century. Among topics covered are: atomic and molecular structure, determination of properties of ions and fundamental particles, the origin of spectra, ion accelerators, and nuclear reactions.

PY 410 Nuclear Physics I 4 (3-2) fs
Prerequisite: PY 207 or PY 407

An introduction to the properties of the nucleus, and the interaction of radiation with matter. A quantitative description is given of natural and artificial radioactivity, nuclear reactions, fission, fusion, and the structure of simple nuclei.

PY 411, 412 Mechanics I, II 3 (2-2) fs
Prerequisites: PY 207 or PY 208, MA 301

A sequence of courses in intermediate theoretical mechanics, including the dynamics of particles and rigid bodies, gravitation, moving reference systems, and the physics of continuous media. An introduction is given to advanced mechanics, including D'Alembert's Principle and Lagrange's equations of motion, with applications.

PY 413 Thermal Physics 3 (3-0) s
Prerequisite: PY 206 or PY 208
Corequisite: MA 301

An intermediate course in the principles of classical thermodynamics and the kinetic theory of gases with an introduction to statistical mechanics. Topics covered include equations of state, entropy, Maxwellian distributions, transport processes, and the statistics of Maxwell-Boltzmann, Bose-Einstein, and Fermi-Dirac.

PY 414, 415 Electricity and Magnetism I, II 3 (2-2) fs
Prerequisite: PY 207 or PY 208
Corequisite: MA 511

An intermediate course in the fundamentals of static and dynamic electricity and electromagnetic theory, developed from basic experimental laws. Vector methods are introduced and employed throughout the course.

PY 416 Optics 3 (2-2) s
Prerequisite: PY 415

An intermediate course in physical optics with the major emphasis on the wave properties of light. Subjects covered include boundary conditions, optics of thin films, interference, diffraction, and the Lorentz atom with applications to absorption, scattering, and laser emission.

PY 499 Special Problems in Physics 1-3 Credits by Arrangement fs
Prerequisite: Permission of department

Study and research in special topics of classical and modern physics. Experimental measurements with emphasis on the treatment and interpretation of data, literature surveys, or theoretical investigations.

Courses for Graduates and Advanced Undergraduates

PY 501, 502 Introduction to Quantum Mechanics I, II 3 (3-0) fs
Prerequisites: MA 511, PY 411 or PY 414

An introduction to the foundations of quantum and wave mechanics, with solutions of the problems of the free particle, harmonic oscillator, rigid rotating molecule, and the hydrogen atom. Approximation methods are developed for more complex atomic systems. Mr. Cobb

PY 503, 504 Introduction to Theoretical Physics I, II 3 (3-0) fs
Prerequisites: PY 412, PY 414, MA 511

An introductory course in theoretical physics which offers preparation for graduate study. Emphasis is on classical mechanics, special relativity, and the motion of charged particles. Topics which are covered include the variational principles of mechanics, Hamilton's equations, canonical transformations, Hamilton-Jacobi theory, and the theory of small vibrations.
Mr. Moss

PY 507 Advanced Atomic Physics 3 (3-0) f
Prerequisites: PY 412, PY 415
Corequisite: PY 501

A study of atomic structure and spectra, with emphasis on the analysis of spectra. Topics include: the alkali spectra, multiplet structure, electron spin, hyperfine structure, moments. Mr. Memory

PY 508 Physical Electronics 3 (2-3) s
Corequisite: PY 414

Statistical theory of matter, collision phenomena in ionized gases, processes at solid surfaces in vacuum and in ionized gases. Mr. Bennett

PY 509 Plasma Physics 3 (3-0) f
Prerequisite: PY 508

Individual and collective motion of charged particles in electric and magnetic fields and through ionized gases. Pinch effect, relativistic streams, conductivities, and runaway electrons. Astrophysical concepts and approximations. Properties of plasmas, including waves, confinement, instabilities and shocks, with applications. Mr. Bennett

PY 510 Nuclear Physics II 4 (3-2) f
Prerequisite: PY 410

The description and analysis of nuclear energy levels, meson theory, nuclear resonance, atomic and molecular magnetism, and cosmic radiation. Principles and experiments in neutron physics are discussed. In the laboratory work, emphasis is placed on gaining experience in independent research. Mr. Waltner

PY 514, 515 Advanced Electricity and Magnetism I, II 3 (3-0) fs
Prerequisite: PY 415

An advanced treatment of electricity and magnetism and electromagnetic theory. Topics include: techniques for the solution of potential problems, development of Maxwell's equations; wave equations; energy, force, and momentum relations of an electromagnetic field; covariant formulation of electrodynamics; radiation from accelerated charges. Mr. Katzin

PY 517 Molecular Spectra 3 (3-0) s
Prerequisites: PY 407, PY 412; PY 507 recommended

Topics include the vibration and rotation of the molecule, nuclear spin, and effects due to electronic motion. Transmission of infrared radiation through atmospheric gases will be discussed, and current molecular band models will be presented. Mr. Patty

PY 518 Radiation Hazard and Protection 3 (3-0) s
Prerequisite: PY 410

Principles of radiation dosimetry and radiation dose units. Radiation hazards to man. Maximum permissible levels of exposure to external and to internal sources of radiation. Methods of providing protection.
Graduate Staff

PY 520 Physical Measurements in Radioactivity 3 (2-2) s
Prerequisite: PY 410

The principles of experimental measurements on radioactive materials are presented and demonstrated through laboratory work. Emphasis is placed on the analytical interpretation of experimental data.
Mr. Lynn

PY 552 Introduction to the Structure of Solids 3 (3-0) s
Prerequisite: PY 207 or PY 407
Corequisite: PY 501

Basic considerations of crystalline solids, metals, conductors and semiconductors. Mr. Memory

PY 599 Senior Research 3 credits fs
Prerequisite: Senior honors program standing, except with special permission

Investigations in physics under the guidance of staff members. Literature reviews, experimental measurements, or theoretical studies.
Graduate Staff

Courses for Graduates Only

PY 600 Planetary Atmospheres 3 (3-0) s
Prerequisite: PY 507

Gas dynamics of atmospheres with emphasis on recent results of rocket, satellite, and interplanetary probes. Theories of the airglow, aurora, and ionosphere are developed. Mr. Manring

PY 601, 602 Theoretical Physics I, II 3 (3-0) fs
Prerequisites: PY 503, PY 514
Corequisite: MA 661

Mathematical and theoretical approach to the relationships between various branches of physics. The restricted theory of relativity, electrodynamics, the theory of electrons, classical field theory, and the general theory of relativity are treated. Mr. Davis

PY 609 High Energy Physics 3 (3-0) s
Prerequisite: PY 510

The experimental and theoretical aspects of nuclear processes at high energy including the classification of mesons and hyperons and their properties, pion-nucleon and nucleon-nucleon interactions, production of

mesons and hyperons, strange particles, spallation, fragmentation, and hyper-fragments. Mr. Waltner

PY 610 Advanced Nuclear Physics 3 (3-0) f
Prerequisite: PY 410; PY 510 recommended
Corequisite: PY 501

A theoretical study of nuclear structure and reactions. Topics include: the deuteron, low-energy nucleon-nucleon scattering, nuclear forces, nuclear moments, nuclear shell theory, collective model, compound nucleus, optical model, and direct reactions. Mr. Park

PY 611 Quantum Mechanics 3 (3-0) f
Prerequisites: PY 502, MA 512

Theory of quantum mechanics with applications to atomic and molecular structure, scattering phenomena, and a semi-classical treatment of the interaction of radiation with matter. Mr. Davis

PY 612 Advanced Quantum Mechanics 3 (3-0) s
Prerequisites: PY 601, PY 611

Dirac's relativistic electron theory, elementary scalar and vector meson field theory. Introduction to quantum electrodynamics and the general theory of quantized fields. Mr. Davis

PY 621 Kinetic Theory of Gases 3 (3-0) f
Prerequisites: PY 501, PY 503, MA 512

The theory of molecular motions, including velocity and density distribution functions; the phenomena of viscosity, heat conduction, and diffusion; equations of state; fluctuations. Mr. Patty

PY 622 Statistical Mechanics 3 (3-0) s
Prerequisite: PY 413
Corequisite: PY 501

A treatment of classical and quantum statistical mechanics with some applications to thermodynamics. Topics include: statistics of Maxwell-Boltzmann, Fermi-Dirac, and Bose-Einstein, canonical ensembles and grand canonical ensembles, ideal Fermi gas, and cooperative phenomena. Mr. Park

PY 641 Non-Inertial Space Mechanics 3 (3-0) s
Prerequisites: PY 601, MA 661
Corequisite: PY 602

The theoretical description of the phenomena of mechanics relating to non-inertial frames of reference with emphasis on applications to space travel and the instrumentation problems of rocketry. Applications to inertial guidance and electromagnetic-inertial coupling effects are also considered. Mr. Davis

PY 695 Seminar 1 (1-0) fs

Reports on topics of current interest in physics. Several sections are offered so that students with common research interests may be grouped together. Graduate Staff

PY 699 Research Credits by Arrangement

Graduate students sufficiently prepared may undertake research in some selected field of physics. Graduate Staff

DEPARTMENT OF PLANT PATHOLOGY

GRADUATE FACULTY

Professors: Don Edwin Ellis, *Head,* Jay Lawrence Apple, Robert Aycock, Carlyle Newton Clayton, Charles Bingham Davey, Teddy Theodore Hebert, George Blanchard Lucas, Richard Robert Nel-

son, Lowell Wendell Nielsen, Charles Joseph Nusbaum, Joseph Neal Sasser, Nash Nicks Winstead

Visiting Professors: David W. French, Frederick Lovejoy Wellman

Professor Emeritus: Samuel George Lehman

Associate Professors: Kenneth Reese Barker, William Earl Cooper, Ellis Brevier Cowling, Charles S. Hodges, Jr., David M. Kline, Royall Tyler Moore, Nathaniel T. Powell, John Paul Ross, Robert T. Sherwood, David Lewis Strider, Hedwig Hirschmann Triantaphyllou

Assistant Professors: Guy Vernon Gooding, Jr., Donald Huisingh, Samuel Forest Jenkins, Jr., Robert Donald Milholland

Adjunct Assistant Professor: Elmer George Kuhlman

The Department of Plant Pathology is equipped with laboratory and greenhouse facilities for graduate study in plant pathology including special equipment for all phases of phytopathological research. The wide range of soil types and climatic areas in North Carolina makes possible the commercial production of a variety of field, vegetable, fruit, and ornamental crops as well as forest trees. Especially favorable opportunities exist for training in diseases caused by nematodes, viruses, fungi, and bacteria which affect many crops. Land facilities for experimental work are available at some sixteen permanent research stations located throughout the state. Student participation in the Plant Disease Clinic provides excellent training and experience in the diagnosis of all types of plant diseases.

Many opportunities for employment in research, extension, and teaching are available to persons with the Master of Science or Doctor of Philosophy degree in plant pathology. There are openings for qualified persons in plant pathology research in the United States Department of Agriculture, state experiment stations and industry. Opportunities exist in foreign service through international and federal organizations as well as in commercial production enterprises. The rapid development of agricultural chemicals for disease control offers numerous opportunities in research, promotion, and service activities.

Courses for Graduates and Advanced Undergraduates

PP 500 Advanced Plant Pathology 3 (2-3) s
Prerequisite: PP 315 or equivalent

An advanced study of the economic importance, symptoms, disease cycles, epiphytology and control of major groups of plant diseases.
Messrs. Jenkins, Kline

PP 503 Diagnosis of Plant Diseases 3 (1-4) summer
Prerequisite: One advanced course in plant pathology, permission of instructor

A study of techniques used in plant disease diagnosis with emphasis on diagnostic value of signs and symptoms for certain types of diseases. Consideration will be given to major sources of descriptive information on plant pathogens and the use of keys for the identification of fungi. (Offered summer 1966 and alternate years.) Mr. Hebert

PP 575 (BO 575, MB 575) THE FUNGI 4 (3-3) s
Prerequisite: BO 301 or equivalent

An overview of the fungi within the framework of a survey of the major classes. Lectures, while covering the major groups systematically, will also include ancillary material such as aspects of ultrastructure, environmental adaptions, sexuality, ontogeny, and economic, including historical importance. Laboratory sessions will provide for study of both known and unknown material to, respectively, familiarize the student with the characteristics of the fungi and an appreciation of the problems and methods of their classification. Mr. Moore

Courses for Graduates Only

PP 601 PHYTOPATHOLOGY I 4 (1-6) f
Prerequisites: PP 315, permission of instructor

A study of the principles of phytopathological research. The course is designed to apply the classical scientific method to disease investigation. Exercises will include appraising disease problems, reviewing literature, laboratory and greenhouse experiments and the evaluation and presentation of data. Mr. Sherwood

PP 602 PHYTOPATHOLOGY II 4 (2-6) s
Prerequisites: PP 315, permission of instructor

The basic concepts of the etiology, pathology, epiphytology and control of plant diseases. Mr. Nusbaum

PP 604 PLANT PARASITIC NEMATODES 2 (1-3) f
Prerequisite: PP 315

A study of morphology, anatomy, physiology and taxonomy of plant parasitic nematodes. Methods of isolating nematodes from soil and plant parts and other laboratory techniques used in the study and identification of nematodes will be considered. Mrs. Triantaphyllou

PP 605 PLANT VIROLOGY 3 (1-6) f
Prerequisites: PP 315, GN 411, and a course in organic chemistry

A study of plant viruses including effects on host plants, transmission, classification, methods of purification, determination of properties, chemical nature, structure and multiplication. (Offered 1965-66 and alternate years.) Mr. Hebert

PP 607 (GN 607) GENETICS OF FUNGI 3 (3-0) f
Prerequisites: GN 512 or equivalent, permission of instructor

Review of major contributions in fungus genetics with emphasis on principles and theories that have evolved in recent developments. (Offered 1966-67 and alternate years.) Mr. Nelson

PP 608 HISTORY OF PHYTOPATHOLOGY 1 (1-0) f
Prerequisites: PP 315, permission of instructor

Development of the science of phytopathology from its early beginnings to the early part of the 20th century. (Offered 1965-66 and alternate years.) Mr. Ellis

PP 609 CURRENT PHYTOPATHOLOGICAL RESEARCH UNDER FIELD CONDITIONS 2 (1-3) s
Prerequisite: Graduate standing

Study of concepts involved, procedures used, and evaluation made in current phytopathological research by plant pathology staff. Visits to various research stations will be made by the class. Mr. Clayton

PP 611 NEMATODE DISEASES OF PLANTS 3 (1-4) s
Prerequisite: PP 604

A study of plant diseases caused by nematodes. Special consideration will be given to host-parasite relationships, host ranges, and life cycles

of the more important economic species. Principles and methods of control will be considered. Mr. Sasser

PP 612 Plant Pathogenesis 3 (2-3) f
Prerequisites: PP 500, permission of instructor

A study of interactions of pathogens and suscept plants. The following major topics will be considered: hydrolytic enzyme systems involved in tissue distintegration; role of enzymes, polysaccharides, and toxins in wilting phenomena; mode of action of toxins in altering plant metabolism, role of growth regulators in hypertrophic responses; alterations in respiration and other physiological processes during pathogenesis; and nature and biochemical basis for disease resistance. (Offered 1966-67 and alternate years.) Mr. Huisingh

PP 690 Seminar in Plant Pathology 1 (1-0) fs
Prerequisite: Permission of seminar chairman

Discussion of phytopathological topics selected and assigned by seminar chairman. Graduate Staff

PP 699 Research in Plant Pathology Credits by Arrangement
Prerequisites: Graduate standing, permission of instructor

Original research in plant pathology. Graduate Staff

DEPARTMENT OF POLITICS

GRADUATE FACULTY

Professors: Preston William Edsall, *Head,* William Joseph Block, Fred Virgil Cahill, Jr., John Tyler Caldwell, Abraham Holtzman

No graduate degrees are offered in politics at North Carolina State University. Graduate programs leading to advanced degrees in this field are offered at the University of North Carolina at Chapel Hill. The courses listed below are eligible for graduate credit when they form a part of an approved graduate program in other departments, and work in politics may serve as a minor field.

Courses for Advanced Undergraduates

PS 401 American Parties and Pressure Groups 3 (3-0) f

PS 406 Problems in State Government 3 (3-0) s

PS 431 International Organization 3 (3-0) f
Prerequisite: PS 201 or permission of department

PS 442 Government and Planning 3 (3-0) s
Prerequisite: PS 201 or permission of department

PS 452 (ED 452) The Legislative Process 3 (3-0) s
Prerequisite: PS 201 or permission of department

PS 481 Political Thought: Plato to the Reformation 3 (3-0) f

PS 485 (ED 485) American Political Thought 3 (3-0) s

PS 491, 492 Seminar in Political Science 3 (3-0) fs
Required of seniors majoring or concentrating in politics; open to other seniors and graduate students with permission of department.

PS 496 Governmental Internship and Seminar 3-6 by arrangement

Courses for Graduates and Advanced Undergraduates

PS 501 Modern Political Theory 3 (3-0) s
Prerequisite: PS 201 or HI 205 or equivalent Mr. Holtzman

PS 502 (ED 502) Public Administration 3 (3-0) fs
Prerequisite: PS 201 or PS 202 or equivalent Mr. Block

PS 510 (EC 510) Public Finance 3 (3-0) f
Prerequisite: The basic course in economics required by the degree granting school

PS 512 American Constitutional Theory 3 (3-0) f
Prerequisite: PS 201 or equivalent Messrs. Cahill, Edsall

Courses for Graduates Only

PS 691 Applied Principles of Public Administration 2-4 by arrangement
Prerequisite: PS 502 or equivalent Graduate Staff

PS 696 Problems in Political Science 2-4 by arrangement
Prerequisite: Advanced graduate standing Graduate Staff

DEPARTMENT OF POULTRY SCIENCE

GRADUATE FACULTY

Professors: Henry Wilburn Garren, *Head,* Clifford Warren Barber, Frank Rankin Craig, Edward Walker Glazener, Charles Horace Hill, Jr., Morley Richard Kare

Associate Professors: William Lowry Blow, William E. Donaldson

The Department of Poultry Science offers the Master of Science degree in poultry science. Doctoral programs are available in physiology, genetics and nutrition.

The Department of Poultry Science occupies Scott Hall, a building containing well-equipped research laboratories, animal rooms, a library and offices. Additional research facilities are located on the University farms and on three outlying farms in western, Piedmont, and eastern sections of North Carolina. New facilities for basic and applied research are under construction both on campus and on the University farms. The research program is comprehensive and ranges from fundamental biochemical, physiological and genetic investigations to poultry management problems.

The demand for men and women with advanced training in poultry science is far greater than the supply. Many opportunities, both domestic and foreign, exist for graduates. These include research and teaching positions in public and private institutions, civil service, and industry.

Courses for Advanced Undergraduates

PO 401 Poultry Diseases 4 (3-3) s
The major infectious, non-infectious and parasitic diseases of poultry are studied with respect to economic importance, etiology, susceptibility,

dissemination, symptoms and lesions. Emphasis is placed upon practices necessary for the prevention, control and treatment of each disease.

PO 402 COMMERCIAL POULTRY ENTERPRISES 4 (3-2) s
Required of majors in poultry science; elective for others with permission of instructor.

Principles of incubation of chicken and turkey eggs; hatchery management; organization and development of plants for the operation and maintenance of a commercial poultry farm for meat and egg production; study of the types of buildings, equipment, and methods of management currently employed by successful poultrymen in North Carolina. Problem.

PO 490 POULTRY SEMINAR 1 (1-0) fs
Required of majors in poultry science.

Current topics and problems relating to poultry science and to the poultry industry are assigned for oral reports and discussion.

Courses for Graduates and Advanced Undergraduates

PO 520 POULTRY BREEDING 3 (2-2) f
Prerequisite: GN 411

Application of genetic principles to poultry breeding, considering physical traits and physiological characteristics—feather patterns, egg production, hatchability, growth, body conformation and utility. Mr. Blow

PO 521 POULTRY NUTRITION 3 (2-3) f
Prerequisite: CH 220 or CH 221
Required of majors in poultry science; elective for others with permission of instructor.

A study of energy, protein, carbohydrate, fat, mineral and vitamin requirements for maintenance, growth and productive purposes. Emphasis will be on the nutritive requirements of the avian species, but the comparative aspects of nutrition will also be discussed. Carbohydrate, fat and amino acid digestion and metabolism will be presented in relation to nutritive requirements. Mr. Donaldson

PO 524 (ZO 524) COMPARATIVE ENDOCRINOLOGY 3 (2-3) s
Prerequisite: ZO 421 or equivalent

Study of the endocrine system with respect to its physiological importance to metabolism, growth, and reproduction. Mr. Garren

Courses for Graduates Only

PO 602 ADVANCED POULTRY NUTRITION 3 (0-6) arranged
Prerequisites: PO 521, CH 551 or equivalent

Students taking this course will conduct a research problem in poultry nutrition. The problem will involve the designing and carrying out of chick experiments based on biochemical considerations. The students will obtain practice in designing nutritional experiments to obtain insight into biochemical problems. Mr. Hill

PO 698 SPECIAL PROBLEMS IN POULTRY SCIENCE Maximum 6 fs
Prerequisite: Graduate standing

Specific problems of study are assigned in various phases of poultry science. Graduate Staff

PO 699 POULTRY RESEARCH Credits by Arrangement fs
Prerequisite: Graduate standing
A maximum of six credits is allowed towards a master's degree.

Appraisal of present research; critical study of some particular problem involving original investigation. Problems in poultry breeding, nutrition, disease, endocrinology, hematology, or microbiology. Graduate Staff

DEPARTMENT OF PSYCHOLOGY

GRADUATE FACULTY

Professors: HOWARD G. MILLER, *Head*, JOHN OLIVER COOK, HAROLD MAXWELL CORTER, SLATER E. NEWMAN

Professor Emeritus: KEY LEE BARKLEY

Associate Professors: NORMAN M. CHANSKY, DONALD W. DREWES, JOSEPH CLYDE JOHNSON, ROBERT E. LUBOW, PAUL JAMES RUST

Adjunct Associate Professor: GILBERT GOTTLIEB

Assistant Professors: EUGENE E. BERNARD, GERALD S. LEVENTHAL

The Department of Psychology offers courses leading to the Master of Science degree. An industrial option includes courses in the application of scientific methods to the study of industrial behavior based on strong research training. An experimental option provides a program with major emphasis on the development of proficiency in experimental methodology in psychological research. Human factors and human engineering training may be elected as part of the industrial or experimental options. A program is offered which provides professional competence in school psychology.

All programs are designed to provide the student with solid grounding in the basic areas of psychology. A set of required core courses includes statistics, social psychology, experimental psychology, psychology of personality, and the theory and method of measurement.

A minimum of thirty semester hours of graduate credit is required for the master's degree, but the actual graduate program for each student is determined on the basis of his individual needs, interests, and accomplishments and very likely will require hours in excess of the minimum.

Admission requirements for graduate study in the Department of Psychology are a minimum of twenty semester credit hours in undergraduate psychology, a "B" average in undergraduate psychology courses, satisfactory grades in other collegiate studies, and satisfactory references from faculty and others in regard to character and quality of work. In some cases provisional acceptance is granted where some of the requirements are not met.

The physical facilities for the training of graduate students in psychology include testing, satistics, general and human engineering laboratories.

In addition to teaching and basic research activities, the Department of Psychology carries on research for industrial, military and other organizations. To facilitate this activity, the Industrial Psychology Center has been established as a special organization within the department.

A limited number of research and teaching assistantships are available annually. These assistantships are usually based on one-third time assignments, but are occasionally for one-half time.

Courses for Advanced Undergraduates

PSY 411 Social Psychology 3 (3-0) s
Prerequisite: PSY 200

The individual in relation to social factors. Socialization, personality development, communication, social conflict and social change.
Messrs. Leventhal, Miller

PSY 438 Industrial Psychology II 3 (3-0) s
Prerequisites: PSY 200, PSY 337

The application of psychological principles to the problems of modern industry; with particular emphasis on human relations and supervision.
Mr. Miller

PSY 441 Human Factors in Equipment Design 3 (3-0) f
Prerequisites: PSY 200, PSY 337 recommended

Human factors in the design of machines and other equipment. Items of equipment are understood as extensions of man's capacity to sense, comprehend, and control his environment. Includes problems in the psychology of information, communication, control, and invention.

PSY 464 Visual Perception for Designers 3 (2-2) s
Prerequisite: PSY 200

The nature of the seeing process and its relation to architecture, industrial arts, and to the industrial engineering and textile design fields. Topics include the basis of sight, perception of color and form, vision and illumination, psychological factors in visual design, and a unit of training planned to improve the student's ability to perceive visual form.
Mr. Bernard

PSY 475 Child Psychology 3 (3-0) s
Prerequisite: PSY 200 or PSY 304

The development of the individual child of the elementary school age will be the inclusive object of study in this course. Emphasis will be placed upon the intellectual, social, emotional, and personality development of the child. Physical growth will be emphasized as necessary to an understanding of the psychological development of the pupil.

PSY 476 Psychology of Adolescence 2 (2-0) fs
Prerequisite: PSY 200

Nature and source of the problems of adolescents in western culture; emotional, social, intellectual and personality development of adolescents.
Mr. Johnson

Courses for Graduates and Advanced Undergraduates

PSY 501 Experimental Psychology 3 (2-3) f
Prerequisite: Nine hours of psychology

Experimental study of problems in general and theoretical psychology with particular emphasis on sensation and perception. Particular attention is paid to problem formation, experimental design and experimental methods. Effective written and oral performance by the student is a basic objective.
Mr. Bernard

PSY 502 Physiological Psychology 3 (3-0) f
Prerequisites: Twelve hours of psychology, including PSY 200, PSY 201

A survey of the physiological bases of behavior including the study of coordination, sensory processes, brain functions, emotions, and motivation.
Messrs. Bernard, Corter

PSY 504 Advanced Educational Psychology 3 (3-0) s
Prerequisite: Six hours in psychology

A critical appraisal of current psychological findings that are relevant to educational practice and theory. Mr. Johnson

PSY 511 Advanced Social Psychology 3 (3-0) f
Prerequisites: PSY 200, PSY 514

A study of social relationships and their psychological bases; emphasis on those aspects of behavior determined by personal interactions; work will involve analysis of representative research studies, and individual projects. Messrs. Leventhal, Miller

PSY 514 Psychological Research Design 1 (1-0) f
Prerequisite: Graduate standing in psychology

The objectives of this course are to acquaint students with current developments in theory and research in several areas of psychological interests; to foster capability to derive experimentally testable hypotheses, and experimental tests of these hypotheses; to write and speak effectively about theory and experimentation in psychology. Graduate Staff

PSY 530 Abnormal Psychology 3 (3-0) s
Prerequisites: PSY 200, PSY 302

A study of the causes, symptomatic behavior, and treatment of the major personality disturbances, emphasis also placed on preventive mental hygiene methods. Mr. Corter

PSY 531S Mental Deficiency 3 (2-2) summer
Prerequisites: Nine hours in psychology and special education

This will be a course in description, causation, psychological factors, education, and sociological aspects of mental retardation. It will emphasize the junior high and high school age group. It is designed primarily for special class teachers of retarded children at this age level. (To be taught in Summer Session only.) Mr. Corter

PSY 535 Tests and Measurements 3 (3-0) fs
Prerequisite: Six hours in psychology

A study of the principles of psychological testing with emphasis on test construction, interpretation of test performance, and use of standard tests in research and education. Mr. Johnson

PSY 540 Human Factors 3 (3-0) f
Prerequisite: Six hours of senior level psychology

An introduction to how the methods and techniques of experimental psychology can be applied to the problems of designing equipment for human use. Mr. Drewes

PSY 550 Mental Hygiene in Teaching 3 (3-0) fs
Prerequisite: Six hours in psychology

A survey of mental hygiene principles applicable to teachers and pupils; practical problems in prevention and treatment of psychological problems in schools; case studies and research. Mr. Corter

PSY 565 Industrial Management Psychology 3 (3-0) s
Prerequisite: Nine hours in psychology

A study of the application of behavioral science, particularly psychology and social psychology, to organizational and management problems. Mr. Miller

PSY 570 Theories of Personality 3 (3-0) s
Prerequisite: Nine hours in psychology

A survey of modern theories of personality with some emphasis on intelligence and cognitive factors. Mr. Corter

PSY 576 Developmental Psychology 3 (3-0) s
Prerequisites: Nine hours in psychology, including PSY 476 or PSY 475

A survey of the role of growth and development in human behavior; par-

ticularly of the child and adolescent periods. This course will pay particular attention to basic principles and theories in the area of developmental psychology. Mr. Johnson

PSY 578 INDIVIDUAL DIFFERENCES 3 (3-0) fs
Prerequisite: Six hours in psychology

Nature, extent, and practical implications of individual differences and individual variation. Graduate Staff

PSY 591 INDIVIDUAL INTELLIGENCE MEASUREMENT 3 (3-0) s
Prerequisite: PSY 570

A practicum in individual intelligence testing with emphasis on the Wechsler-Bellevue, Stanford-Binet, report writing, and case studies.
Mr. Corter

Courses for Graduates Only

PSY 604 ADVANCED EXPERIMENTAL PSYCHOLOGY: LEARNING AND MOTIVATION 3 (3-0) s
Prerequisite: PSY 501 or equivalent

The objectives of this course are to promote familiarity with the kinds of research currently being conducted within the areas of "learning and motivation;" to foster effective performance in writing, speaking and reading in this area, in the derivation of hypotheses capable of experimental test and in the design of experiments to test them.
Messrs. Cook, Lubow, Newman

PSY 606 BEHAVIOR THEORY 3 (3-0) s
Prerequisites: PSY 200, a course in learning, experimental psychology and statistics

A study of the most fundamental considerations in behavior theory. Such topics as criteria of scientific meaningfulness, the nature of scientific explanation, the application of formal, logical techniques to theory analysis, the nature of probability, operationism, intervening variables, etc., will be covered. The aim of the course is to develop skill in handling theoretical concepts, the ability to analyze and evaluate theories, to deduce hypotheses from them, and to devise means of testing them. Mr. Cook

PSY 607 ADVANCED INDUSTRIAL PSYCHOLOGY I 3 (3-0) f
Prerequisites: Nine hours in psychology and statistics or concurrent with statistics

Application of scientific methods to the measurement and understanding of industrial behavior. Messrs. Drewes, Miller

PSY 608 ADVANCED INDUSTRIAL PSYCHOLOGY II 3 (3-0) s
Prerequisite: PSY 607

Application of scientific methods to the measurement and understanding of industrial behavior. Messrs. Drewes, Miller

PSY 610 THEORIES OF LEARNING 3 (3-0) f or s
Prerequisite: PSY 604

The objectives of this course are to promote learning on the theories currently used to explain how learning and forgetting occur so that testable consequences of these theories can be derived and so that the theories and their testable consequences are capably written and spoken about.
Messrs. Cook, Newman

PSY 635 PSYCHOLOGICAL MEASUREMENT 3 (3-0) f
Prerequisites: ST 511 or equivalent, and twelve hours of psychology

Theory of psychological measurement. Statistical problems and techniques in test construction. Mr. Drewes

PSY 640 ADVANCED HUMAN FACTORS 3 (3-0) s
Prerequisites: Twelve hours in psychology, including PSY 540, MA 421, statistics or concurrent with statistics

This course is designed to provide the student with (1) an understanding of the major areas of experimental and theoretical work being done in the field of human factors engineering and (2) experience in applying the large body of knowledge available in this field to the design of man-machine systems. Graduate Staff

PSY 690 SEMINAR IN INDUSTRIAL PSYCHOLOGY 3 (3-0) fs

Scientific articles, analysis of experimental designs in industrial psychology, and study of special problems of interest to graduate students in industrial psychology. Messrs. Baldwin, Drewes, Miller

PSY 692 PERSONALITY MEASUREMENT 3 (2-3) fs
Prerequisites: PSY 570, PSY 591

Theory and practicum in individual personality testing of children and adults with emphasis on projective techniques, other personality measures, report writing and case studies. Mr. Corter

PSY 693 PSYCHOLOGICAL CLINIC PRACTICUM Maximum 12 fs
Prerequisite: Eight hours in psychology

Clinical participation in interviewing, counseling, psychotherapy and administration of psychological tests. Practicum to be concerned with adults and children. Mr. Corter

PSY 699 RESEARCH IN PSYCHOLOGY Credits by Arrangement fs

Individual or group research problems; a maximum of six credits is allowed toward the master's degree. Graduate Staff

DEPARTMENT OF RURAL SOCIOLOGY

GRADUATE FACULTY

Professors: SELZ CABOT MAYO, *Head,* EDGAR JOHN BOONE, CHARLES HORACE HAMILTON

Associate Professors: HARRY GEDDIE BEARD, ROBERT JOHN DOLAN, LAWRENCE WILLIAM DRABICK, CULPEPPER PAUL MARSH, GLENN C. MCCANN, JAMES NEAL YOUNG

The Department of Rural Sociology offers the Master of Science and the Doctor of Philosophy degrees.

Graduate students studying for the Doctor of Philosophy degree usually take one semester of course work in the Department of Sociology at the University of North Carolina at Chapel Hill. Students seeking the Master of Science degree may take courses at Chapel Hill. However, they will be able to complete their entire program at North Carolina State.

The physical and educational resources of the rural sociology department available to graduate students include a departmental library of bulletins, monographs, and other materials consisting of several thousand items, accumulated over a period of thirty years, and catalogued in indexed files. Laboratory equipment consists of calculating machines, drawing table and instruments, chart making materials, cameras, typewriters, and statistical aids. Also at the disposal of the graduate student are automobiles for field surveys and IBM tabulating equipment operated by the Computing Center.

The Department of Rural Sociology prepares graduate students for a variety of positions. Men and women with graduate degrees

in rural sociology have opportunities for careers in college teaching, sociological research, social statistics, social work, administration of social organizations and governmental agencies, agricultural journalism, and in branches of the government's foreign service relating to agriculture and the developing areas of the world.

Institutions offering employment to graduates are land-grant colleges, agricultural experiment stations, and extension services; other colleges and universities; the United States Departments of Agriculture, State, and Health, Education and Welfare; state departments of health, education and welfare; farm journals and newspapers, and voluntary social agencies such as Red Cross, Community Chest, Boy Scouts, and National Tuberculosis Association. Each year outstanding graduate students are awarded research or teaching assistantships, usually requiring the devotion of half of their time to a research project or teaching function as appropriate. Cooperative research work in the department frequently provides opportunities for part-time employment for other graduate students.

Courses for Graduates and Advanced Undergraduates

RS 511 Rural Population Problems 3 (3-0) f
Prerequisite: RS 301

A study of population growth, rates of change, and distribution. Considerable attention is given to the functional roles of population, i.e., age, sex, race, residence, occupation, marital status, and education. The dynamic aspects of population are stressed: fertility, mortality, and migration. Population policy is analyzed in relation to national and international goals. A world view is stressed throughout. Mr. Hamilton

RS 512 Rural Family Living 3 (3-0) f
Prerequisite: RS 301

Values, patterns, and levels of rural family living. Differentials and factors related thereto in the world, the nation, and North Carolina. Analysis of selected problems, programs, policies, and methods of study. Mr. Davis

RS 513 (ED 513) Community Organization 3 (3-0) f
Prerequisite: RS 301

Community organization is viewed as a process of bringing about desirable changes in community life. Community needs and resources available to meet these needs are studied. Democratic processes in community action and principles of community organization are stressed, along with techniques and procedures. The roles of leaders, both lay and professional, in community development are analyzed. Mr. Mayo

RS 523 Sociological Analysis of Agricultural Land Tenure Systems 3 (3-0) f
Prerequisite: Three hours of sociology

A systematic sociological analysis of the major agricultural land tenure systems of the world with major emphasis on the problems of family farm ownership and tenancy in the United States. Mr. Hamilton

RS 534 (HI 534) Agricultural Organizations and Movements 3 (3-0) s
Prerequisite: Three hours of sociology

A history of agricultural organizations and movements in the United States and Canada principally since 1865, emphasizing the Grange, the

Farmers' Alliance, the Populist revolt, the Farmers' Union, the Farm Bureau, the Equity societies, the Nonpartisan League, cooperative marketing, government programs, and present problems. Mr. Noblin

RS 541 Social Systems and Planned Change 3 (3-0) f
Prerequisite: Three hours of sociology

A study of social agencies and programs and their implementation through specific organizations in dynamic relation with the people whom they serve. Consideration is given to the relation of these agencies and programs to community structure and forces in rural society; coordination of the several types of agencies and programs; professional leadership in the local community; and, problems in stimulating local leadership and participation. Mr. Marsh

RS 611 Research Methods in Sociology 3 (3-0) f
Prerequisite: Six hours of sociology

Designed to give the student a mature insight into the nature of scientific research in sociology. Assesses the nature and purpose of research designs, the interrelationship of theory and research, the use of selected techniques and their relation to research designs, and the use of modern tabulation equipment in research. Mr. McCann

RS 621 Rural Social Psychology 3 (3-0) f
Prerequisite: Six hours of sociology

Treats the genetic development of the rural personality and the interrelationship of the individual and the rural society. Studies of social psychological factors related to rural leadership, morale, social organization, and social change, and examines the attitudes and opinions of rural people on current local and national issues. Mr. McCann

RS 631 Population Analysis 3 (3-0) s
Prerequisite: Six hours of sociology

Methods of describing, analyzing, and presenting data on human populations: distribution, characteristics, natural increase, migration, and trends in relation to resources. Mr. Hamilton

RS 632 Rural Family 3 (3-0) s
Prerequisite: Six hours of sociology

Emphasis is placed on the development of an adequate sociological frame of reference for family analysis; on discovering both the uniquely-cultural and common-human aspects of the family by means of cross-cultural comparisons; on historical explanations for variability in American families with special concern for the rural family; and on analyzing patterns of family stability and effectiveness. Graduate Staff

RS 633 The Rural Community 3 (3-0) s
Prerequisite: Six hours of sociology

The rural community is viewed in sociological perspective as a functioning entity. A method of analysis is presented and applied to eight "dimensions," with emphasis on the unique types of understanding to be derived from measuring each dimension. Finally, the effect of change on community integration and development is analyzed. Mr. Mayo

RS 641 (ST 641) Statistics in Sociology 3 (3-0) s
Prerequisite: ST 513

The application of statistical methods of sociological research. Emphasis on selecting appropriate models, instruments, and techniques for the more frequently encountered problems and forms of data. Mr. Hamilton

RS 652 Comparative Rural Societies 3 (3-0) s
Prerequisite: Six hours of sociology

Sociological analysis of rural societies around the world with particular reference to North and South America. Special emphasis is given to cultural and physical setting, population composition, levels of living, relation-

ship of the people to the land, structure and function of the major institutions and forces making for change. Mr. McCann

RS 653 Theory and Development of Rural Sociology 3 (3-0) s
Prerequisite: Six hours of sociology
Required of all master's and doctoral candidates in rural sociology; recommended for all graduate minors.

Designed to meet two objectives: (1) to introduce the student to the study of current sociological theory, and (2) to survey events and trends in the historical development of rural sociology. Mr. Hamilton

RS 690 Seminar Credits by Arrangement fs
A maximum of two credits is allowed toward the master's degree, and four credits toward the doctorate.

Appraisal of current literature; presentation of research papers by students; progress reports on departmental research; review of developing research methods and plans; reports from scientific meetings and conferences; other professional matters. Graduate Staff

RS 699 Research in Rural Sociology Credits by Arrangement fs
Prerequisite: Permission of graduate study committee chairman

Planning and execution of research, and preparation of manuscript under supervision of graduate committee. Graduate Staff

DEPARTMENT OF SOCIOLOGY AND ANTHROPOLOGY

GRADUATE FACULTY

Professors: Selz Cabot Mayo, *Head,* Elmer Hubert Johnson
Associate Professors: Herbert Collins, Horace Darr Rawls, James Neal Young
Assistant Professor: Edward Charles Lehman, Jr.

Courses for Advanced Undergraduates

SOC 401 Human Relations in Industrial Society 3 (3-0) fs
Prerequisite: Senior standing or permission of instructor

Selected societies about the world are contrasted with American society to demonstrate the correlation between technology and general behavior patterns, both within industry and in the total social order. The patterns of adjustment by the individual to the organizational framework (business concern, manufacturing enterprise, etc.) are analyzed in terms of social status, social roles, work norms, and attitudes. The social significance of major characteristics of contemporary industry is considered in terms of such topics as enlargement of the geographic bounds of the human community, development of occupational specialization, alteration of the character of inter-group inter-action, and the growing integration of American culture. The interrelationships between industry and social change are discussed to show the effect of new social conditions upon industrial operations and the effect of technological change upon the family, school, church, and government. The contribution of industry to social progress is analyzed to promote the student's understanding of the dynamic quality of the social environment within which he will function.

SOC 402 Urban Sociology 3 (3-0) fs
Prerequisites: SOC 202, permission of instructor

The course begins with a study of the factors behind the organic growth of cities. The relationship between the physical design of cities and their social organization is discussed. This is followed by a detailed analysis of new developments in the serving of human needs (adequate housing, and

the design of physical and social structures for religious, educational, public welfare, and recreational activities). Socio-psychological aspects of life in an urbanized society are compared with those of predominantly agricultural societies. The increasing integration of urban and rural living is emphasized. Finally, the changing character of uban life is seen in the resulting demand for city and regional planning and the use of administrative personnel having both technical and social backgrounds.

SOC 405 Social Work I 3 (3-0) fs
Prerequisites: SOC 202, permission of instructor

An introductory course, designed to acquaint students with the various types of public and private social work and with remedial and preventive programs in applied sociology; social psychiatry, health, public welfare, and recreation.

SOC 406 Social Work II 3 (2-2) fs

The subjects covered include emergence and present status of social work as a profession, roles, role conflict, and the generic base of methods in social work. Attention is focused on casework, group work and community organization. Some time is devoted to research efforts and to modes of administration. Each student is given an opportunity to participate in the current operations of one agency in the community.

SOC 411 Community Relationships 3 (3-0) fs
Prerequisites: SOC 202, permission of instructor

A survey of the institutions, organizations, and agencies to be found in modern communities; the social conditions or problems, such as recreation, health, welfare, etc., with which they deal; their inter-relationship and the trend toward over-all planning.

SOC 414 Social Structure 3 (3-0) fs
Prerequisites: Six hours in sociology, permission of instructor

Studies of the major social institutions and systems of stratification; the organization of social systems as, for example, religion, education, and government; the functions of such structural components as age and sex groups, vocational and professional groups, and social classes.

SOC 416 Research Methods 3 (3-0) fs
Prerequisites: Nine hours in sociology, permission of instructor

An analysis of the principle methods of social research; the development of experiments; schedules and questionnaires; the measurement of behavior.

SOC 418 (RS 418, ED 418) Educational Sociology 3 (3-0) fs
Prerequisite: Three hours in sociology

An investigation of the educational institution in a sociological framework. Analyzes the school as a social system, roles of the functionaires of education, relationships within the student body, effects of social factors upon the learning experience, reciprocal school-community relationships, adult education, and higher education in American society.

Courses for Graduates and Advanced Undergraduates

SOC 501 (ED 501) Leadership 3 (3-0) fs
Prerequisites: SOC 202, SOC 301 or equivalent

A study of leadership in various fields of American life; analysis of the various factors associated with leadership; techniques of leadership. Particular attention is given to recreational, scientific, and executive leadership procedures. Mr. Young

SOC 502 Society, Culture, and Personality 3 (3-0) fs
Prerequisites: SOC 202, SOC 301 or equivalent

Human personality is studied from its origins in primary groups through

its development in secondary contacts and its ultimate integration with social norms. While comparative anthropological materials will be drawn upon, emphasis is placed upon the normal personality and the adjustment of the individual to our society and to our culture. The dynamics of personality and character structure are analyzed in terms of the general culture patterns and social institutions of society. Mr. Rawls

SOC 505 The Sociology of Rehabilitation 3 (3-0) fs
Prerequisites: SOC 202, SOC 301 or equivalent

The course stresses the social and cultural implications of the rehabilitation approach. Emphasis is placed upon the social and personal problems of physically and mentally handicapped persons. The interrelationships of the major social environments are considered at length in this regard. Objectives of the rehabilitation processes are analyzed in terms of the sociology of work. A major portion of the course is devoted to rehabilitation as a profession, particular attention being given to the diverse roles of specialists in this field. Graduate Staff

SOC 510 Industrial Sociology 3 (3-0) fs
Prerequisites: SOC 202, SOC 301 or equivalent

Industrial relations are analyzed as group behavior with a complex and dynamic network of rights, obligations, sentiments, and rules. This social system is viewed as an interdependent part of total community life. The background and functioning of industrialism are studied as social and cultural phenomena. Specific social problems of industry are analyzed.
Graduate Staff

SOC 511 Sociological Theory 3 (3-0) fs
Prerequisites: Six hours in sociology, graduate standing or permission of instructor

Study of the interdependence of theory and method; the major theoretical and methodological systems; and examination of selected cases of research in which theory and method are classically combined.
Mr. Rawls

SOC 590 Applied Research 3 (3-0) fs
Prerequisites: SOC 202, SOC 301 or equivalent

A study of the research process with particular emphasis upon its application to action problems. The development of research design to meet action research needs receives special attention. Mr. Marsh

DEPARTMENT OF SOIL SCIENCE

GRADUATE FACULTY

Professors: Ralph J. McCracken, *Head,* William Victor Bartholomew, Charles Bingham Davey, James Walter Fitts, Eugene J. Kamprath, William A. Jackson, James Fulton Lutz, Charles B. McCants, William Garland Woltz, William Walton Woodhouse, Jr.

Associate Professors: Jack V. Baird, Stanley Walter Buol, Maurice Gayle Cook, George A. Cummings, Preston Harding Reid, Richard J. Volk, Sterling Barg Weed

Visiting Associate Professor: Arvel Hatch Hunter

Assistant Professors: Frederick Russell Cox, James W. Gilliam, Robert E. McCollum, Clifford K. Martin

Visiting Assistant Professors: Robert Bancroft Cates, James Lester Walker, Donovan L. Waugh

The Department of Soil Science offers training leading to the degrees of Master of Science and Doctor of Philosophy in the fields

of soil chemistry, soil fertility, soil physics, soil genesis, soil microbiology, and soil conservation.

Modern facilities are provided for soils graduate teaching and research in Williams Hall. Office and laboratory space is assigned each student. Literature relative to soils and related subjects is maintained in a departmental library. Facilities for graduate research include radioactive and stable isotope laboratories containing automatic recording scalers and liquid scintillation apparatus, a mass spectrometer, amino acid analyzer, X-ray diffraction apparatus with fluorescence, differential thermal analysis, infrared spectrophotometer, atomic absorption spectrophotometer, polarizing microscope, high speed centrifuges, thin sectioning apparatus, and other modern equipment. Photomicrographic equipment is available for photographing thin sections and microorganisms.

Service laboratories for soil and plant analyses are available as well as special preparation rooms for soil and plant samples. Greenhouses and growth chambers situated at the rear of Williams Hall are easily accessible for controlled plant studies. Field experiments are made on the sixteen research farms and four experimental forests owned or operated by the state. Located throughout North Carolina, the farms and forests include a wide variety of soil and climatic conditions. One of the largest and best equipped soil testing laboratories in the United States is operated by the North Carolina Department of Agriculture in Raleigh. Special studies on various problems of soil testing can be made in conjunction with this laboratory.

Strong supporting departments greatly increase the graduate student's opportunities for a broad and thorough training. Included among those departments in which graduate students in soil science work cooperatively or obtain instruction are crop science, biological and agricultural engineering, botany, chemistry, economics, forest management, geology, mathematics, plant pathology, physics, and statistics.

Courses for Graduates and Advanced Undergraduates

SSC 511 Soil Physics 4 (3-3) f
Prerequisites: SSC 200, PY 212

Physical constitution and analyses; soil structure, soil water, soil air and soil temperature in relation to plant growth. Mr. Lutz

SSC 522 Soil Chemistry 4 (3-3) s
Prerequisites: SSC 200, SSC 553, CH 433 or equivalent

A consideration of the chemical and colloidal properties of clay and soil systems, including ion exchange and retention, soil solution reactions, solvation of clays, and electrokinetic properties of clay-water systems.
Mr. Weed

SSC 524 Mass Spectrometry 2 (1-3) s
Prerequisites: SSC 302, CH 433 or equivalent

An examination of theoretical and analytical aspects of mass spectrometry and stable isotopic techniques; application of these methods to biochemical research. (Offered 1966-67 and alternate years.)
Mr. Volk

SSC 532 (MB 532) Soil Microbiology 3 (3-0) s
Prerequisites: SSC 302, BO 312, CH 220

The more important microbiological processes that occur in soils; decomposition of organic materials, ammonification, nitrification, and nitrogen fixation. Mr. Bartholomew

SSC 541 Soil Fertility 3 (3-0) f
Prerequisites: SSC 302, SSC 341

Soil conditions affecting plant growth and the chemistry of soil and fertilizer interrelationships. Factors affecting the availability of nutrients. Methods of measuring nutrient availability. Mr. Kamprath

SSC 551 Soil Morphology, Genesis and Classification 3 (3-0) f
Prerequisites: SSC 200; SSC 302 or SSC 341; MIG 120

Morphology: Study of concepts of soil horizons and soil profiles and chemical, physical and mineralogical parameters useful in characterizing them. Genesis: Critical study of soil forming factors and processes. Classification: Critical evaluation of historical development and present concepts of soil taxonomy with particular reference to great soil groups as well as discussion of logical basis of soil classification Mr. Buol

SSC 553 Soil Mineralogy 3 (2-3) f
Prerequisites: SSC 200, SSC 341, MIG 330 or equivalent

Composition, structure, classification, identification, origin, occurrence, and significance of soil minerals with emphasis on primary weatherable silicates, layer silicate clays, and sesquioxides. Messrs. Cook, Weed

SSC 560 North Carolina Soils and Their Management 3 (3-0) summer
Prerequisites: SSC 200, SSC 302 or SSC 341

Field studies of selected soil series in the coastal plain, Piedmont and mountain areas of North Carolina. Discussion of management practices that should be associated with the various soils under different types of farming. (Offered summer of 1967 and alternate years.)
Messrs. Kamprath, McCracken

SSC 590 Special Problems Credits by Arrangement
Prerequisites: SSC 200, SSC 302

Special problems in various phases of soils. Problems may be selected or will be assigned. Emphasis will be placed on review of recent and current research. Graduate Staff

Courses for Graduates Only

SSC 622 Physical and Chemical Properties of Soils 4 (4-0) s
Prerequisites: SSC 511, SSC 522, CH 433, MA 301 or equivalent

An examination in depth of current ideas concerning the physics and chemistry of soil and clay systems. Topics will include ion exchange, molecular adsorption, electrokinetics, relations between mineral structures, and their physical and chemical properties, and the properties of adsorbed water. Emphasis will be determined by student interest and by current literature. (Offered 1966-67 and alternate years.) Mr. Weed

SSC 651 Pedology 3 (3-0) f
Prerequisites: SSC 522, SSC 511

A critical study of current theories and concepts in soil genesis and morphology; detailed study of soil taxonomy. Topics include weathering and clay mineral genesis as related to soil morphology and genesis, functional analyses of soil genesis, properties of and processes responsible for soil profiles formed under various sets of soil forming factors, classification theory and logic as applied to soil classification, structure of soil classification schemes. Any of these topics may be emphasized, according to student interests. (Offered 1965-66 and alternate years.)
Mr. McCracken

SSC 672 Soil Properties and Plant Development 3 (3-0) s
Prerequisites: CH 551, SSC 522 or equivalent

A detailed examination of the effects of soil factors in the development of crop plants. Segments of the course will treat soil transformation processes of both organic and inorganic constituents, concepts of nutrient availability, and the relation of plant development indices to specific soil properties. (Offered 1965-66 and alternate years.) Mr. Jackson

SSC 690 Seminar 1 (1-0) fs
Prerequisite: Graduate standing in soil science
A maximum of two credits is allowed toward the master's degree, but any number toward the doctorate.

Scientific articles, progress reports in research and special problems of interest to agronomists reviewed and discussed. Graduate Staff

SSC 693 Colloquium in Soil Science Credits by Arrangement
Prerequisite: Graduate standing in soil science

Seminar-type discussions and lectures on specialized and advanced topics in soil science.

SSC 699 Research Credits by Arrangement
Prerequisite: Graduate standing in soil science
A maximum of six credits is allowed toward the master's degree, but any number toward the doctorate. Graduate Staff

SCHOOL OF TEXTILES

GRADUATE FACULTY

Professors: Malcolm Eugene Campbell, *Dean*, Clarence Monroe Asbill, Jr., John Francis Bogdan, Kenneth Stoddard Campbell, David Marshall Cates, *Graduate Administrator in Textile Chemistry*, Elliot Brown Grover, Dame Scott Hamby, *Graduate Administrator in Textile Technology*, Joseph Alexander Porter, Jr., Henry Ames Rutherford, William Edward Shinn, Robert W. Work

Visiting Professor: Harley Young Jennings

Associate Professors: Richard D. Gilbert, Thomas H. Guion, Arthur Courtney Hayes, William Clifton Stuckey, Jr.

Assistant Professors: Ernest Bezold Berry, Bhupender S. Gupta

The School of Textiles offers programs leading to the Master of Science in Textile Technology, Master of Textile Technology, and Master of Science in Textile Chemistry.

The fundamental objectives of the graduate program in the School of Textiles are to develop the student's ability to initiate and conduct independent investigations which lead to the development of new knowledge, and to stimulate the thought processes associated with learning and decision making. These objectives are accomplished through programs designed to increase the general knowledge of the student and to develop a more comprehensive understanding of the major field through study and research.

The program of study for the graduate student in textile technology may be arranged to develop a broad background in advanced technology and, at the same time, emphasize areas such as fiber and yarn technology, fabric technology, knitting technology, or quality control. Students may minor in such fields as experimental

statistics, economics, mathematics, physics, engineering, psychology, and political science.

The programs of study for the Master of Science degree include a minimum of 30 semester credit hours of advanced courses, including a thesis based on research conducted by the student, and proficiency in one foreign language. The plan of course work and the research activities for the Master of Science degree are designed to prepare the student for a career in research, quality control, and other technical phases of the textile industry. The student is also prepared to continue his educational program to more advanced degrees. The minimum requirement for a Master of Textile Technology is the satisfactory completion of 36 semester credit hours of advanced courses. There is no thesis or foreign language requirement for the Master of Textile Technology. This program is designed to offer the student advanced technology without the emphasis on research. Students pursuing this degree are encouraged to minor in economics with emphasis in the area of management.

In the Department of Textile Technology current research activities include fundamental studies of man-made fiber properties, characterization of combed and carded yarns, influence of variation in linear density of in-process materials as related to finished product quality, and processing problems as associated with the newest developments in materials and supplementary equipment.

In the Department of Textile Chemistry research emphasis is on absorption studies, textile chemical processes, new materials and new methods, and modification of fibrous polymers. The objective of the graduate program is to stimulate basic research and to train scientists at the graduate level in the general field of fiber chemistry. Strong supporting programs are maintained in chemistry, chemical engineering, mathematics, experimental statistics, and physics.

The physical resources of the School of Textiles are at the disposal of all graduate students. Separate research laboratories for both physical and chemical investigations are available for graduate research. The research and educational programs of the school have facilitated the development of a competent staff of instructors and researchers. A shop is available in Nelson Textile Building for construction and maintenance of apparatus.

A number of teaching assistantships and research fellowships are available. The stipends range from $1,800 to $3,600, with some fellowships including tuition and fees.

The demand by industry and educational institutions for graduates with advanced degrees constantly exceeds the supply. The financial remuneration is not only larger, but professional development and recognition are generally more readily attained.

For a description of courses offered by the School of Textiles, see Textile Chemistry, page 197, and Textile Technology, page 198.

DEPARTMENT OF TEXTILE CHEMISTRY

(For a listing of graduate faculty and other information, see School of Textiles, page 195.)

Courses for Advanced Undergraduates

TC 403, 404 Textile Chemical Technology 3 (3-0) fs
Prerequisites: TC 304, CH 223
Required of seniors in textile chemistry.

The chemistry involved in the wet processing of fibrous systems, especially dyeing, printing and finishing. The course emphasizes principles and includes a study of the various classes of dyes and their application to all important textile fibers and blends of fibers; preparatory and bleaching processes; roller printing and print formulations for important dye classes; nature and application of finishes for textiles. Mr. Campbell

TC 405, 406 Textile Chemical Technology Laboratory 2 (0-6) fs
Required of seniors in textile chemistry.
To be taken concurrently with TC 403 or 404. Two 3-hour laboratories per week.

TC 412 Textile Chemical Analysis II 3 (2-3) f
Prerequisites: CH 215, TC 304
Required of students in textile chemistry.

Analysis of textile materials involving specialized instruments, and techniques such as spectrophotometry, pH measurements, electrometric titration, viscometry, etc.

TC 421 Fabric Finishing I 2 (2-0) s
Prerequisite: TC 201
Students in textile chemistry may not take this course for degree credit.

A general course in fabric finishing designed for students not majoring in textile chemistry. Emphasis placed on finishes used on garment-type fabrics, including stabilization finishes, water repellency, crease resistance, moth and mildew proofing, fire-proofing, etc. Emphasis on chemistry of finishes varied to fit requirements of students.

TC 461 (CH 461) Chemistry of Fibers 3 (3-0) s
Prerequisite: CH 223
Required of seniors in textile chemistry.

A lecture course emphasizing the theory of fiber structure; the relationship between the chemical structure and physical properties of natural and man-made fibers; the nature of the chemical reactions which produce degradation of fibers; the production of man-made fibers.
Mr. Rutherford

Courses for Graduates and Advanced Undergraduates

TC 501 Seminar in Textile Chemistry 2 (2-0) s
Prerequisite: TC 403
Required of seniors in textile chemistry.

The course is designed to familiarize the student with the principal sources of textile chemical literature and to emphasize the importance of keeping abreast of developments in the field of textile chemistry. Particular attention is paid to the fundamentals of technical writing. (Reports. Lectures arranged.) Mr. Campbell

TC 521 Textile Chemical Analysis III 3 (2-3) fs
Prerequisite: TC 421 or equivalent

Elective for students in textile technology; no credit allowed for students majoring in textile chemistry.

The work includes a survey of organic chemistry, with emphasis on organic surfactants, warp sizes, and fabric finishes of all types; the identification of fibers by chemical means; the qualitative and quantitative analysis of fiber blends by chemical means, the identification of finishes; the evaluation techniques for dyed and finished materials.

Graduate Staff

TC 562 (CH 562) CHEMISTRY OF HIGH POLYMERS 3 (3-0) s
Prerequisite: CH 431

Principles of condensation and free radical polymerization; kinetics and molecular weight description; copolymerization and composition; emulsion polymerization; structure. Messrs. Cates, Gilbert

Courses for Graduates Only

TC 605 PHYSICAL CHEMISTRY OF DYEING 3 (3-0) s
Prerequisite: CH 433

Development of principles of thermodynamics, emphasizing applications in dye and fiber chemistry. Mr. Cates

TC 606 CHEMISTRY OF FIBER-FORMING HIGH POLYMERS 3 (3-0) f
Prerequisite: CH 431

Structure and properties of fibers; thermodynamics of sorption and solution; solution properties; molecular weight determination; flow properties; mechanical properties. Mr. Cates

TC 698 SEMINAR FOR TEXTILE CHEMISTRY 1 (1-0) fs

Discussion of scientific articles of interest to textile industry; review and discussion of student papers and research problems.

Graduate Staff

TC 699 TEXTILE RESEARCH FOR TEXTILE CHEMISTRY Credits by Arrangement

Problems of specific interest to the textile industry will be assigned for study and investigation. The use of experimental methods will be emphasized. Attention will be given to the preparation of reports for publication. The master's thesis may be based upon the data obtained.

Graduate Staff

DEPARTMENT OF TEXTILE TECHNOLOGY

(For a listing of graduate faculty and other information, see School of Textiles, page 195.)

Courses for Advanced Undergraduates

TX 430 CONTINUOUS FILAMENT YARNS 3 (2-2) fs
Prerequisite: TX 303
Required of students in fiber and yarn technology and knitting technology; elective for others.

A study of properties and processes applicable only to filament yarns such as texturizing and bulking. Detailed studies of throwing systems, engineering requirements of equipment, and yarn property changes resulting from processing.

TX 436 STAPLE FIBER PROCESSING 3 (2-2) fs
Prerequisite: TX 303
Required of students in fiber and yarn technology; elective for others.

A study of special systems of processing long, staple, natural and man-made fibers, including woolen, worsted, direct spinning, Turbo Stapler, or Pacific Converter, and sliver to yarn methods. New concepts and research findings as applied to all yarn processes.

TX 441 Flat Knitting 3 (2-2) f
Prerequisite: TX 342
Required of seniors in knitting technology; elective for others.

A study of the leading types of flat knitting machines including warp knitting machines, design possibilities and fabric adaptability.

TX 442 Knitted Fabrics 3 (2-2) fs
Prerequisite: TX 342
Required of seniors in textile technology and knitting technology.

Design, analysis, and production of knitted fabrics, including flat, circular, and warp types. The economic aspects of the knitting process as a method of clothing production. Introduction to garment design, production and marketing.

TX 444 Garment Manufacture 3 (2-2) s
Prerequisite: TX 342
Required of seniors in knitting technology; elective for others.

A study of circular latch needle and spring needle machines for knitted fabric production. Styling, cutting and seaming of the basic garment types for underwear and outerwear, standard seam types; high-speed sewing machines.

TX 447, 448 Advanced Knitting Laboratory 2 (0-4) fs
Prerequisite: TX 342
Required of seniors in knitting technology; elective for others.

Systematic study of circular hosiery mechanisms; hosiery types and constructions. Seamless hosiery production methods utilizing the newer synthetic yarns, toe closing methods, finishing processes, and marketing are emphasized.

TX 449 Tricot Knitting 3 (2-2) s
Prerequisite: TX 342
Elective for juniors and seniors.

A study of basic types of tricot knitting machines with emphasis on mechanisms and fabrics. Attention is given to warp preparation methods applicable to the tricot machine, the characteristics of yarn made from natural and synthetic fibers as they affect processing into warp knitted fabrics, machine settings for proper qualities and ratios; economics of warp knitting, and end uses. Attention is given to fabric design and analysis.

TX 478 Design and Weaving 3 (2-2) fs
Prerequisite: TX 366
Required of students in fabric technology; elective for others.

Advanced study of special weave formations and the techniques and equipment necessary to form these fabrics. Studies in depth of new developments and research findings in the areas of warp preparation, design, weaving and fabric formation.

TX 483 Textile Cost Methods 3 (3-0) fs
Prerequisites: TX 303, TX 365
Required of seniors in textiles except those in management option.

A survey of cost methods applicable to textile operations with emphasis on decision making as related to costing and cost control.

TX 485 Mill Design and Organization 4 (3-2) fs
Prerequisites: TX 303, TX 365
Required of students in textile technology curriculum; for seniors in final semester only.

Application of economic principles to textile factoring, hedging, and other buying and selling problems. Inventory control, organization, and departmental functions of textile companies. Technical problems of plant site selection, plant design and layout, and selection of equipment. Layout of a mill by each student.

TX 490 DEVELOPMENT PROJECT I 1-3 fs
Prerequisites: Senior standing, permission of instructor

A problem of independent study assigned to seniors in the major field of study serving also as the laboratory period for senior level courses. (Laboratory hours arranged.)

Courses for Graduates and Advanced Undergraduates

TX 521 TEXTILE TESTING II 3 (2-2) f
Prerequisite: TX 327

Advanced techniques for measuring properties of natural and man-made fibers, yarns, and fabrics. Interrelations of raw material quality, processing characteristics, and end product properties. The application of the laws of physical sciences to evaluation of textile materials.
Messrs. Hamby, Stuckey

TX 522 TEXTILE QUALITY CONTROL 3 (2-2) s
Prerequisite: TX 521

Quality control systems for textile operations. Defect prevention methods, isolation of processes contributing to substandard quality, relationship between quality control department and operating division. Laboratory design, equipment and personnel selection, installation of quality control systems. Messrs. Hamby, Stuckey

TX 525 ADVANCED TEXTILE MICROSCOPY 2 (1-2) fs
Prerequisite: TX 327

Experiments, lectures and demonstrations in more advanced techniques of textile microscopy. Detailed studies of structures of fibers covered in lecture series, supplemented by experiments on lecture topics. Detailed study of all types of microscopes and their uses in textiles. Preparation of slides for photography. Uses of photomicrographic equipment.
Mr. Stuckey

TX 551 COMPLEX WOVEN STRUCTURES 3 (2-2) s
Prerequisite: TX 478

The development of design specifications for complex fabrics as related to fabric geometry, functional and aesthetic properties and manufacturing limitations. Mr. Berry

TX 575 FABRIC ANALYTICS AND CHARACTERISTICS 3 (3-0) fs
Prerequisite: TX 302 or TX 366 or TC 511

Analysis and study of textile fabrics to determine the composite effects of yarn and fiber properties. Fabric design features that are related to mechanical as well as aesthetic properties. Engineering and fabrics based on utilization of other mixtures and homogeneous blends of natural and man-made fibers. Messrs. Berry, Porter

TX 590 SPECIAL PROJECTS IN TEXTILES 1 to 3 fs
Prerequisites: TX 327, senior standing, permission of instructors

Special studies in either the major or minor field of the advanced undergraduate or graduate student. These special studies will take the form of current problems of the industry, independent investigations in the areas of textile testing and quality control, seminars and technical presentations, both oral and written. Graduate Staff

TX 591 SPECIAL TOPICS 1 to 4 fs
Prerequisite: Permission of instructor

Critical study of current and advanced topics in textiles.
Graduate Staff

TX 598 Textile Technology Seminar 2 (2-0) fs
Prerequisites: Senior standing, permission of instructor

Lecture and discussion periods are designed for students who are particularly interested in the yarn manufacturing aspects of the textile industry. Subject matter will include such various aspects as training methods, safety programs, modern mill design, specialized techniques in setting rates, employee relations, and developments that arise from technical meetings. Mr. Grover, Graduate Staff

Courses for Graduates Only

TX 601, 602 Staple Fiber Structures 3 (2-2) fs
Prerequisite: Graduate standing

Studies of advanced techniques in textile production; the technological aspects of fiber properties in relation to processing; studies of research findings and application of these to processing equipment.
Messrs. Bogdan, Grover, Hamby

TX 621 Textile Testing III 2 (2-0) s
Prerequisite: TX 522 or equivalent

Design of textile laboratories, including conditioning equipment and instruments required for specific needs: performance of tests and analysis of data on industrial problems; specialized physical tests; inter-laboratory tests and analysis; study of A.S.T.M. specifications and work on task groups for the A.S.T.M. Society. Messrs. Gupta, Hamby

TX 631 Synthetic Fibers 2 (2-0) fs
Prerequisite: TX 430 or TX 436 or equivalent

Lectures and projects on advanced problems relative to the properties and processing of man-made continuous filament and staple fiber yarns.
Messrs. Grover, Hamby

TX 641, 642 Advanced Knitting Systems and Mechanisms 3 (3-0) fs
Prerequisite: TX 441 or equivalent

A critical study of inventions which have contributed to the development of the modern knitting industry; knitting needles and their adaption for specific uses; means for mounting them for individual and *en masse* operation; construction and functioning of cooperating elements including sliders, jacks, sinkers, dividers, pressing elements, narrowing and tensioning and draw-off motions, regulating mechanisms, timing and control chains and cams. Use will be made of patent literature which covers important developments in the hosiery industry. Mr. Shinn

TX 643, 644 Knitting Technology 3 (1-4) fs
Prerequisites: Graduate standing, eight credits in knitting technology

Problems of specific interest to the knitting industry will be assigned for study and investigation. The use of experimental methods will be emphasized. Attention will be given to the preparation of reports for publication. Graduate Staff

TX 651, 652 Fabric Development and Construction 3 (1-4) fs
Prerequisite: Graduate standing

Application of advanced technology to the development and construction of woven fabrics. Mr. Porter

TX 698 Seminar 1 (1-0) fs

Discussion of scientific articles of interest to the textile industry; review and discussion of student papers and research problems.
Graduate Staff

TX 699 TEXTILE RESEARCH Credits by Arrangement

Problems of specific interest to the textile industry will be assigned for study and investigation. The use of experimental methods will be emphasized. Attention will be given to the preparation of reports for publication. The master's thesis may be based upon the data obtained.

Graduate Staff

DEPARTMENT OF ZOOLOGY

GRADUATE FACULTY

Professors: BERNARD STEPHEN MARTOF, *Head,* FREDERICK SCHENCK BARKALOW, JR., DANIEL SWARTWOOD GROSCH, REINARD HARKEMA, DON WILLIAM HAYNE, THOMAS LAVELLE QUAY, RALPH WINSTON STACY

Professor Emeritus: BARTHOLOMEW BRANDNER BRANDT

Adjunct Professor: THEODORE ROOSEVELT RICE

Associate Professors: CHARLES WALTER ALLISTON, WILLIAM WALTON HASSLER, FRANCIS EUGENE HESTER, ROBERT E. LUBOW, LAWRENCE E. METTLER, GROVER CLEVELAND MILLER, JOHN ANTHONY SANTOLUCITO, ALASTAIR MCDONALD STUART

Assistant Professors: JOHN EYRES HOBBIE, DONALD BION HORTON

Adjunct Assistant Professors: JOSEPH WILLIAM ANGELOVIC, THOMAS WADE DUKE, CLAIRE L. SCHELSKE, JOHN G. VANDENBERGH

The Department of Zoology offers to qualified students the opportunity to earn the Master of Science and the Doctor of Philosophy degrees. Students may specialize in many areas: behavior, general ecology, population dynamics, limnology, marine biology, fisheries biology, wildlife biology, taxonomy and ecological life histories of parasites, comparative morphology and systematics of vertebrates, cellular and comparative physiology, and endocrinology.

The department is located in Gardner Hall where facilities for a wide variety of research activities are available. A two-million dollar addition to Gardner Hall will be completed by the fall of 1966. Excellent opportunity for many types of ecological studies is provided in the extensive natural areas of state parks; some are only six miles from campus. Several off-campus laboratories have recently been constructed and are available to students and staff:

(1) The Radiobiological Laboratory at Beaufort, North Carolina, is supported by the Bureau of Commercial Fisheries and by the Atomic Energy Commission. Studies of productivity, cycling of elements through the marine environment, and effects of radionuclides on morphology and physiology of marine organisms are in progress. Modern research laboratories with special facilities for irradiating and maintaining organisms are provided.

(2) The Hatteras Marine Laboratory is located at the southern end of Hatteras Island, North Carolina, where a variety of interesting biological habitats occur. Cape Hatteras is the closest point to the Gulf Stream north of Daytona Beach, Florida. Both northern and southern faunas are found in adjacent waters. Recently the main building was completely renovated. It contains offices and laboratories for general use. Another building located on the waterfront houses a large dissecting room and facilities for maintaining live specimens.

(3) The Pamlico Estaurine Laboratory is a newly established facility located near Aurora, North Carolina. The research at this facility is primarily concerned with biological productivity and population dynamics. The physical facilities include a seven-room laboratory as well as living quarters for the resident director. Additional laboratory space and a dormitory for visiting scientists and graduate students will soon be available.

By mutual agreement, a student may choose to do research with any member of the graduate staff. A student will make up a plan of study after discussing his interests and objectives with his major professor and advisory committee. Those courses will be selected which best prepare him for his particular interests. Advanced courses in other departments provide a variety of subjects for minor fields of study: botany, entomology, genetics, statistics, biomathematics, biochemistry, psychology, and other related sciences. The student is given the opportunity to develop a high order of independent thought, broad knowledge, technical skills, and thorough training in investigative techniques. Strong emphasis is placed on active participation in seminars, practice in the methods of original research and preparation of manuscripts for publication in scientific journals.

A variety of positions is open to students holding advanced degrees. There is a great need for professional zoologists in teaching and research in institutions of higher learning and in industry. Research personnel are especially in demand in behavior, physiology and other medically related sciences. Numerous positions with the Fish and Wildlife Service, the Soil Conservation Service, the Forest Service, and the Park Service are open to zoologists.

A prospective student must submit Graduate Record Examination scores for the verbal, quantitative, and advanced tests with the application for admission.

Courses for Graduates and Advanced Undergraduates

ZO 510 Adaptive Behavior of Animals 4(3-3)f
Prerequisite: ZO 421 or permission of instructor

The comparative study of animal behavior including a treatment of the physiological mechanisms involved in behavior and the adaptive significance of behavior. Both invertebrates and vertebrates will be studied.
Mr. Stuart

ZO 513 Comparative Physiology 4 (3-3) f
Prerequisite: ZO 421

An advanced treatment of the nervous, circulatory, respiratory, and digestive systems. Lectures, collateral reading, and laboratory experiments will emphasize basic physiological mechanisms. Mr. Santolucito

ZO 515 Growth and Reproduction of Fishes 3 (2-3) s
Prerequisites or Corequisites: GN 411, ZO 420, ZO 441

The biology of fishes: physiology, anatomy, pathology, behavior, and genetics. This course is designed especially for graduate students in fisheries. Several trips to research laboratories will be taken.
Mr. Hester

ZO 517 Population Ecology 3 (3-0) s
Prerequisites: ZO 442; ST 511 or equivalent

The dynamics of natural populations. Current work, theories and problems dealing with population growth, fluctuations, limitation and patterns of dispersion, the ecological niche, food chains and energy flow.
Mr. Hayne

ZO 519 Limnology 4 (3-3) f
Prerequisite: ZO 442 or equivalent

A study of inland waters. Lectures dealing with physical, chemical, and biological factors that affect freshwater organisms. General principles are illustrated in the laboratory and in the field. Mr. Hobbie

ZO 524 (PO 524) Comparative Endocrinology 3 (2-3) s
Prerequisite: ZO 421 or equivalent

Study of the endocrine system with respect to its importance to metabolism, growth and reproduction. Laboratory techniques and demonstrations.
Merrs. Garren, Santolucito

ZO 532 See GN 532, Biological Effects of Radiations. 3 (3-0) s

ZO 540 See GN 540, Evolution. 3 (3-0) f

ZO 542 Herpetology 3 (2-3) s
Prerequisites: ZO 223, ZO 421

The biology of the amphibians and reptiles: systematics, life history, anatomy, behavior, physiology, and ecology. Graduate Staff

ZO 544 Mammalogy 3 (2-3) s
Prerequisites: BS 100, ZO 201 and permission of instructor

The classification, indentification, and ecology of the major groups of mammals. Mr. Barkalow

ZO 550 See GN 550, Experimental Evolution. 3 (3-0) s

ZO 553 Principles of Wildlife Science 5 (3-4) f
Prerequisites: ZO 223, ZO 442

The principles of wildlife management and their application are studied in the laboratory and in the field. Mr. Barkalow

ZO 555 (MB 555) Protozoology 4 (2-6) f
Prerequisite: ZO 450 or equivalent

The biology of the protozoa: morphology, physiology, ecology, genetics, reproduction, evolution, systematics, and life-cycles of both free-living and parasitic taxa. Laboratory study will stress recognition of selected forms and demonstrate techniques used to prepare specimens for microscopic examinations. Graduate Staff

ZO 581 Parasitology I 4 (2-4) f
Prerequisite: ZO 223, ZO 315 or equivalent

The study of the morphology, biology and control of the parasitic protozoa and helminths of man, domestic and wild animals. (Offered 1967-68 and alternate years.) Messrs. Harkema, Miller

ZO 582 See ENT 582 Medical and Veterinary Entomology. 3 (2-3) s

ZO 588 (BO 588) Cell Physiology 3 (3-0) s
Prerequisite: ZO 421 or BO 421 or permission of instructor

A study of fundamental physiological processes at the cellular level with emphasis on basic principles. Messrs. Roberts, Troyer

ZO 589 (BO 589) Cell Physiology Laboratory 1 (0-3) s
Corequisite: ZO 588 or BO 588

Experimental approaches to the study of physiological processes at the cellular level. Messrs. Roberts, Troyer

ZO 590 Special Studies Credits by Arrangement
Prerequisites: Twelve semester credits in zoology and permission of instructor
A maximum of three credits allowed toward the bachelor's degree, six toward the master's, and nine toward the doctorate.

The investigation of a particular problem in zoology.

Graduate Staff

ZO 592 Topical Problems 1-3 arranged
Prerequisite: Graduate standing or permission of instructor

Organized, formal lectures and discussions of a special topic.

Staff

ZO 603 Advanced Parasitology 3 (2-3) s
Prerequisite: ZO 581

The study of the theoretical and practical aspects of parasitism; taxonomy, physiology, and immunology of animal parasites.

Messrs. Harkema, Roberts

ZO 604 See ANS 604, Experimental Animal Physiology. 4 (2-4) f

ZO 610 Current Problems in Animal Behavior 4(3-3)f
Prerequisite: ZO 510 or permission of instructor

Lectures, discussions, seminars and laboratories. The course will treat in detail selected problems in the behavior of invertebrates and vertebrates that are presently being intensely studied. The relationship of behavior to physiology, ecology and current progress in other related biological fields will be emphasized. Mr. Stuart

ZO 619 Advanced Limnology 3 (1-6) s
Prerequisite: ZO 519

A study of primary productivity, population interactions, and effects of pollution. An experimental approach is used in the laboratory.

Mr. Hobbie

ZO 621 Fishery Science 3 (2-3) f
Prerequisites: ZO 420, ST 511, a course in calculus

An analysis of fishery research methods. Population enumeration and dynamics. The relationship between fluctuations in natural populations and environmental factors. (Offered 1967-68 and alternate years.)

Mr. Hassler

ZO 690 Seminar 1 (1-0) fs

The presentation and defense of original research and current literature.

Graduate Staff

ZO 699 Research in Zoology Credits by Arrangement
Prerequisites: Twelve semester credits in zoology, permission of instructor
A maximum of six credits is allowed toward the master's degree; any number toward the doctorate.

Original research related to the student's thesis. Graduate Staff

State's graduate faculty includes men active in scholarship and research. The relationship between professor and student provides personal attention and guidance.

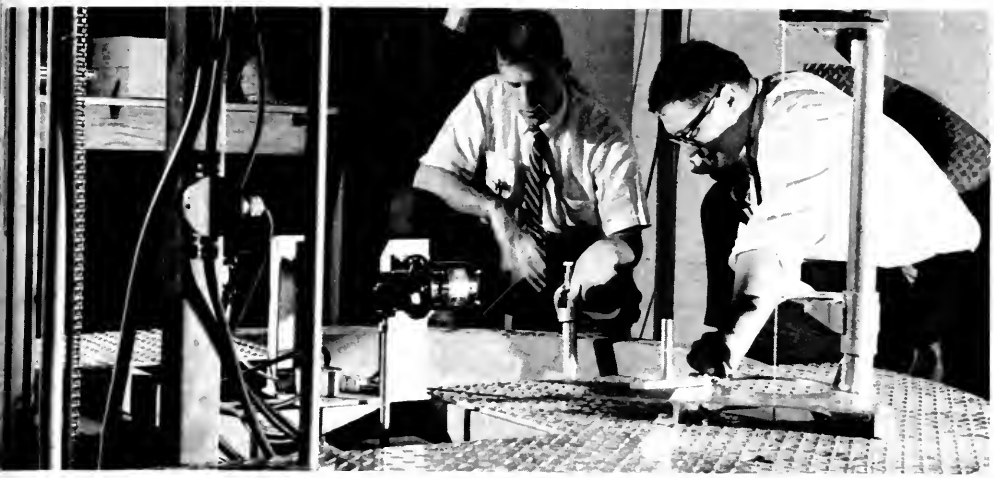
Vital to the multimillion dollar agricultural research programs at Stat are the extensive greenhouse facilities

A current research project in mechanical engineering concerns tire stress and strain.

One of State's newest classroom buildings, the General Laboratory Building provides laboratory, classroom, and office space for the School of Physical Sciences and Applied Mathematics.

Graduate study frequently requires highly specialized equipment. Agricultural engineering students use environmental control chambers to define plant growth dynamics.

The D. H. Hill Library, important among State's research facilities, houses more than 332,000 volumes. Carrel and study rooms are available for graduate students.

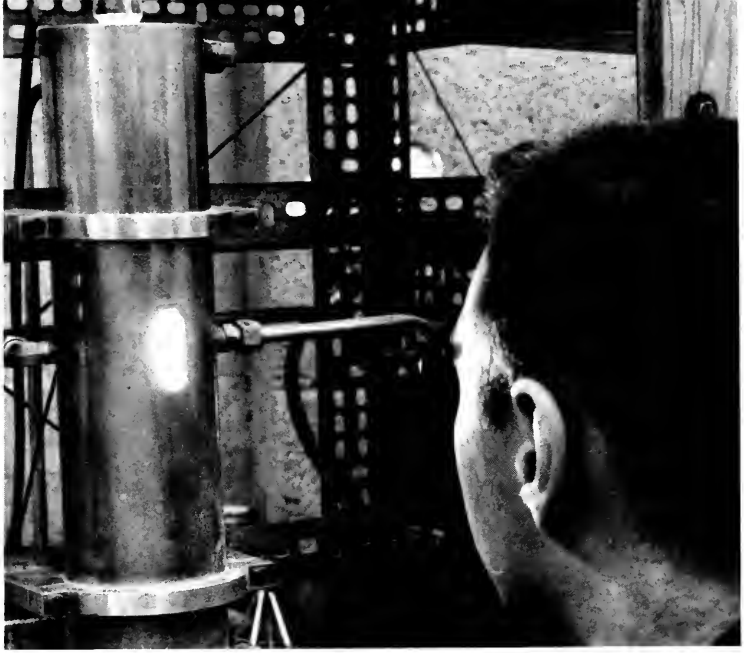


Nuclear research is an important field for advanced study. Here students examine the cobalt source for State's nuclear reactor.

For a civil engineering student the highway may serve as a laboratory. Several departments in the School of Engineering cooperate on highway research.

State's nuclear reactor, the first to be located on a university campus, is housed in the Burlington Nuclear Laboratory, a center for research on atomic energy.

Students in the pulp and paper curriculum train for careers in one of the South's leading industries.



A graduate student in ceramic engineering checks the growth of a single crystal sapphire in a study of the properties of materials.

The processing of fibers and yarns requires complex quality control measures, observed by textiles students in the physical testing laboratory.

*GRADUATE FACULTY

NORTH CAROLINA STATE UNIVERSITY
at Raleigh

SIDNEY ADDELMAN, *Adjunct Associate Professor of Experimental Statistics.*
Ph.D., Iowa State University.

CHARLES WALTER ALLISTON, *Associate Professor of Zoology.*
Ph.D., North Carolina State.

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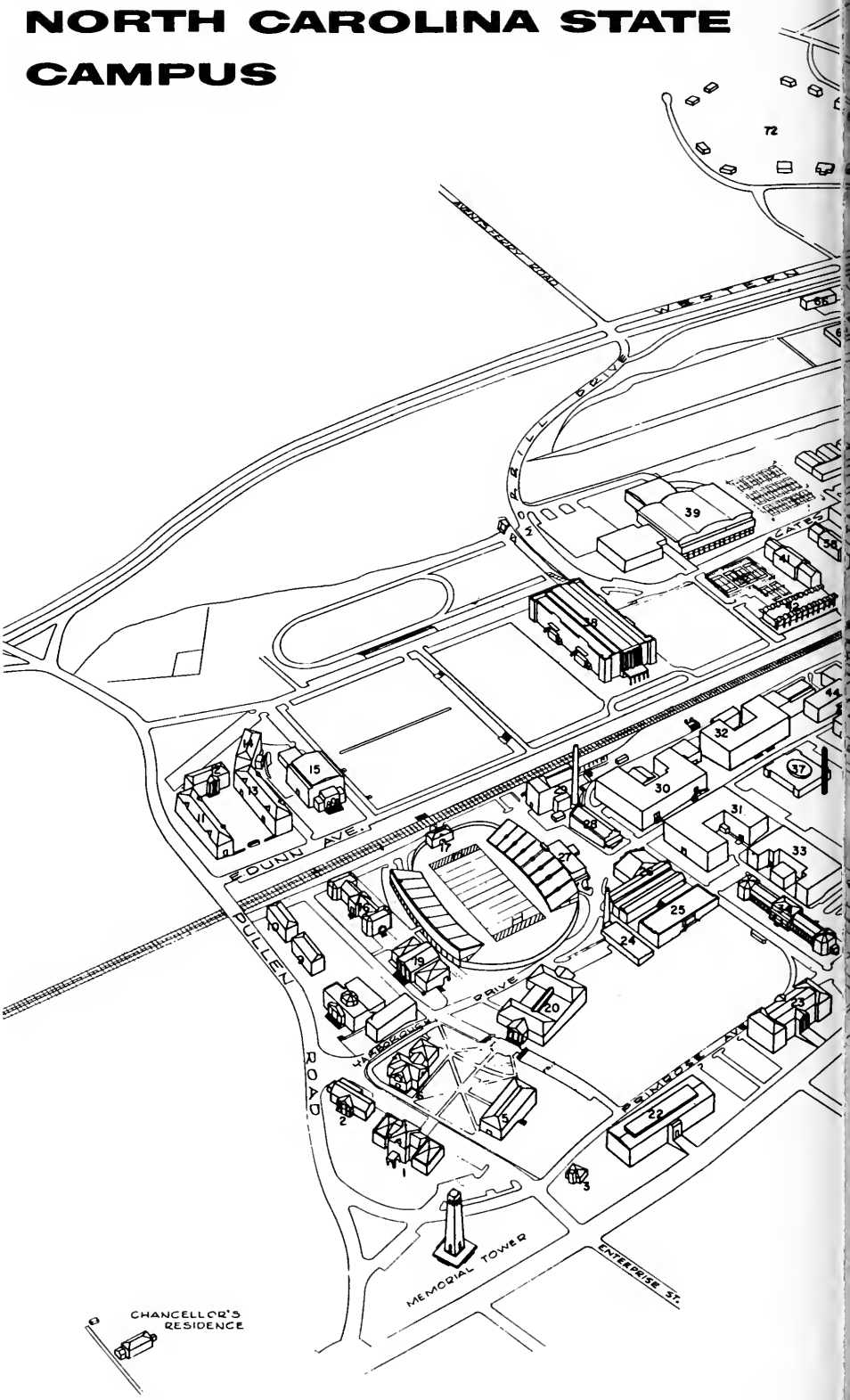
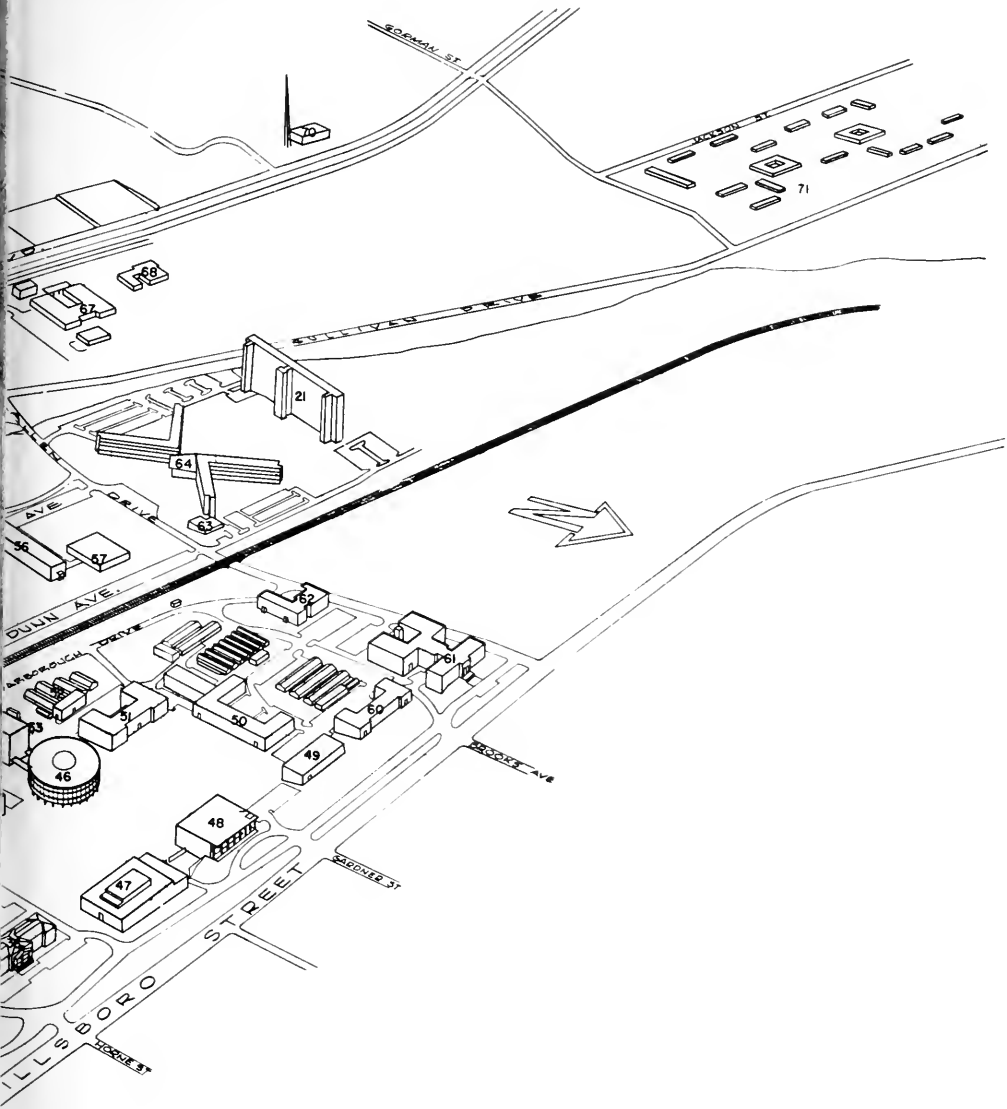
INDEX

NORTH CAROLINA STATE CAMPUS





1. HOLLADAY
2. ALUMNI
3. PRIMROSE
5. PEELE
6. WATAUGA
7. BROOKS
8. FOURTH
9. GOLD
10. WELCH
11. BAGWELL
12. BERRY
13. BECTON
14. CLARK
15. FRANK THOMPSON GYM
16. SYME
17. FIELD HOUSE
19. KING
20. LEAZAR
21. LEE
22. TOMPKINS
23. WINSTON
24. CERAMICS
25. PAGE
26. PARK SHOPS
27. MORRIS
28. LAUNDRY
29. POWER PLANT
30. RIDDICK
31. DANIELS
32. MANN
33. WITHERS
34. 1911 BUILDING
35. RICKS
36. PATTERSON
37. BURLINGTON NUCLEAR LABS
38. WILLIAM NEAL REYNOLDS COLISEUM
39. CARMICHAEL GYMNASIUM
41. ALEXANDER
42. STUDENT SUPPLY STORE
43. BUREAU of MINES
44. BROUGHTON
45. POLK
46. HARRELSON
47. D. H. HILL LIBRARY
48. ERDAHL-CLOYD UNION
49. SCOTT
50. GARDNER
51. WILLIAMS
52. AGRONOMY GREENHOUSES
53. LABORATORY BUILDING
54. OWEN
55. TURLINGTON
56. TUCKER
57. CAFETERIA
60. KILGORE
61. NELSON
62. MANGUM
63. PRINT SHOP
64. BRAGAW
65. BRANDON P. HODGES
66. ROBERTSON
67. AGRICULTURAL ENGINEERING
68. ANIMAL DIAG LABORATORY
70. WUNC-TV
71. MARRIED STUDENT HOUSING
72. FRATERNITY HOUSING